

40MHz 12K Line Scan CCD Camera (Preliminary)

P2-80-12K40

Camera User's Manual



3-Aug-05
03-32-10128-03
www.dalsa.com

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1

Introduction

1.1 Camera Highlights

- 12288 pixels, $7\mu\text{m} \times 7\mu\text{m}$, 100% fill factor
- 8 taps, bilinear CCD
- 320 MHz data rate (40 MHz $\times$ 8)
- 24 kHz line rates
- 10x antiblooming
- Programmable integration time, line rate, gain, offset, test pattern and diagnostics
- Serial interface (ASCII, 9600 baud, adjustable to 19200, 57600, 115200), through Camera Link™
- Full Camera Link™ configuration interface
- Flat-field correction – minimizes sensor FPN and PRNU, lens vignetting and non-uniform lighting
- Single 12V to 15V power supply
- Compact design
- 8-bit output from 10-bit digitization

Description

With 12288 pixels, 8 taps, 24kHz line rates, and a data rate totaling 320MHz, DALSA's new camera offers twice the throughput of any existing line scan camera giving you the ability to increase the amount of inspection you perform and reduce product costs. Its industry standard Camera Link interface provides powerful programmability and versatility including flat field correction, programmable line rate, exposure time, gain, and diagnostics.

To speed setup and system debugging, the camera can output a test pattern and end-of-line sequence to help track the path of data through an acquisition system.

1.2 Camera Specifications

Table 1: Operating Requirements and Ranges

Feature / Specification	Units	Value			Notes
Sensor Features					
Imager Format		Bilinear, center tap architecture			
Resolution	pixels	12288			
Pixel Fill Factor	%	100			
Pixel Size	μm	7 x 7			
Output Format (# of taps)		8			
Antiblooming		100x			
Optical Interface	Units				Notes
Back Focal Distance					
Sensor die to mounting plate	mm	4.0 ±0.25mm			
Sensor Alignment					Refer to Figure 19: Sensor Alignment Reference.
x	μm	±180			
y	μm	±180			
z	μm	±250			
Θz	°	0.6			
Parallelism/Tilt	μm	<350			
Die Surface Flatness	μm	100			
Lens Mount		Adapter required			M3 x 0.5-6H x 7.0 deep (4x) lens adapter mounting holes. Refer to the mechanical drawing in section 4.1 Mechanical Interface for details on where the holes are located.
Mechanical Interface	Units				Notes
Camera Size	mm	170x114			
Mass	Kg	.75			
Connectors					
data connector		2 x MDR26 (female)			
power connector		Hirose 6-pin (male)			
Electrical Interface	Units	Min	Nom	Max	Notes
Input Voltage	Volts		+12 to +15		
Power Dissipation	W		13.5	17	
Operating Temperature	°C	25		40	Measured at the front plate.
Data Output Format	Bits	8		8	
Operating Ranges					
Value	Units	Min	Nom	Max	Notes
Line Rate	kHz	5		24	
Data Rate	MHz			40	
Gain control	dB	-10		+10	

Table 2. Performance Specifications

		Min Gain			Nom Gain			Max Gain			Notes
Environment Conditions	Units	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Data Rate	MHz	40	40	40	40	40	40	40	40	40	
Gain Setting	dB	-10	-10	-10	0	0	0	+10	+10	+10	
Ambient Air Temperature	°C	20		30	20		30	20		30	
		Min Gain			Nom Gain			Max Gain			Notes
Performance Specifications	Units	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Broadband Responsivity	DN/(nJ/cm ²)	3.4	3.7	4.0	8.0	8.8	9.4	24.7	27.2	29.7	
Dynamic Range	Ratio	210:1									
RMS Noise, max	DN						1.12				
FPN uncorrected	DN						8				
FPN corrected	DN						2				
PRNU uncorrected							<20%				1
PRNU corrected	DN						8				2
pixel to pixel							TBD				
DC Offset	DN				5		10				
SEE	nJ/cm ²						30				
NEE	pJ/cm ²						138				
Saturation level	DN					245					

Notes:

DN=Digital Numbers (0-255); also known as gray levels

All measurements are valid for front plate temperatures in still air.

All measurements used a Tungsten halogen light source, 3250K bulb temp. and 750nm cutoff filter

1. % of signal at calibration level
2. At 128DN video level

1.3 Image Sensor

Figure 1: IT-P9-12288 Sensor Block Diagram

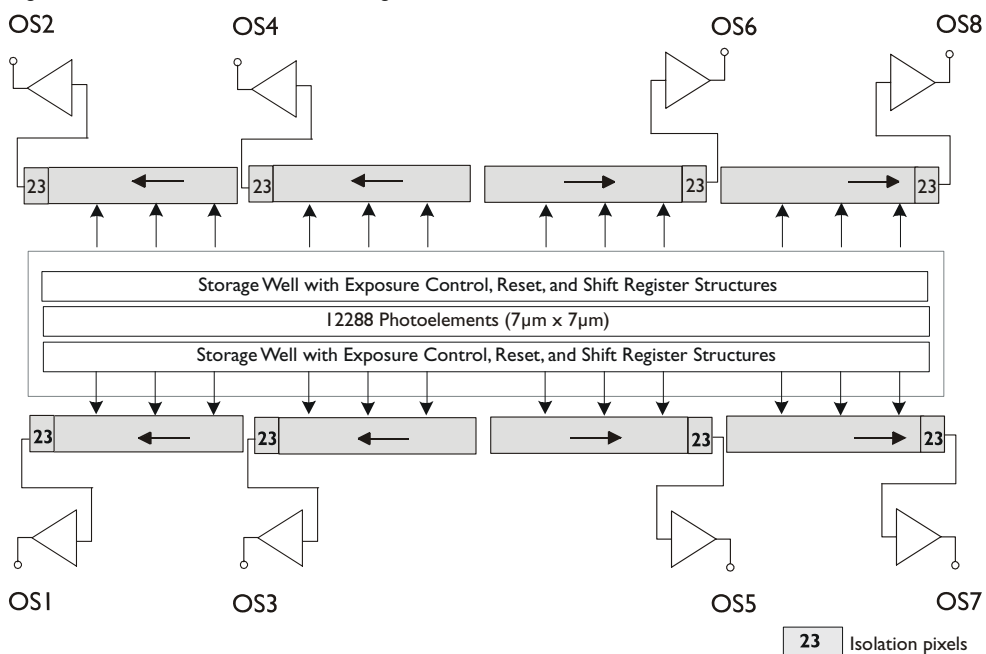


Table 3: Pixel Readout

Tap #	First Pixel	Last Pixel	Increment
1	1	3071	2
2	2	3072	2
3	3073	6143	2
4	3074	6144	2
5	9215	6145	-2
6	9216	6146	-2
7	12287	9217	-2
8	12288	9218	-2

2

Camera Hardware Interface

2.1 Installation Overview

This installation overview assumes you have not installed any system components yet.

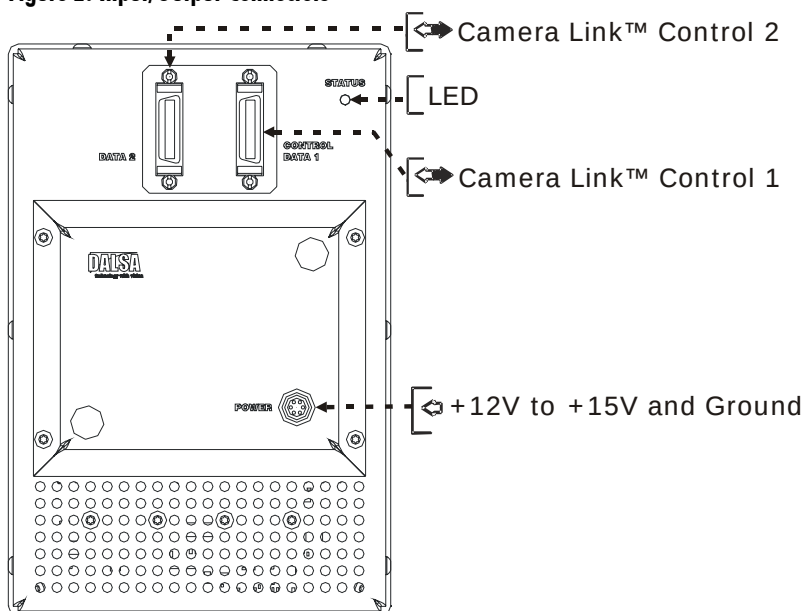
In order to set up your camera, you should take these initial steps:

1. Power down all equipment.
2. Following the manufacturer's instructions, install the framegrabber (if applicable). **Be sure to observe all static precautions.**
3. Install any necessary imaging software.
4. Before connecting power to the camera, test all power supplies. **Ensure that all the correct voltages are present at the camera end of the power cable** (The Camera Performance Specifications on page 6 list appropriate voltages). Power supplies must meet the requirements defined in section 2.2.2 Power .
5. Inspect all cables and connectors prior to installation. Do not use damaged cables or connectors or the camera may be damaged.
6. Connect data, serial interface, and power cables.
7. After connecting cables, apply power to the camera. After a few seconds, the LED on the back of the camera should be green to indicate that the camera is operating and ready to receive commands.

2.2 Input/Output

The camera uses:

- Two high-density 26-pin MDR26 connectors for Camera Link control signals, data signals, and serial communications. See section 2.2.1 Camera Link Pinouts and Control Signals.
- A DB9 female power connector. See section 2.2.2 Power Connector.

Figure 2: Input/Output Connectors

2.2.1 Camera Link Pinouts and Control Signals

Camera Link Pinout

Figure 3: MDR26 Connector

Mating Part: 3M 334-31 series

Cable: 3M 14X26-SZLB-XXX-0LC**

Table 4: Camera Link Full Configuration

Full Configuration Up to an additional 2 Channel Link Chips			
Camera Connector	Right Angle Frame Grabber	Channel Link Signal	Cable Name
1	1	inner shield	Inner Shield
14	14	inner shield	Inner Shield
2	25	Y0-	PAIR1-
15	12	Y0+	PAIR1+
3	24	Y1-	PAIR2-
16	11	Y1+	PAIR2+
4	23	Y2-	PAIR3-
17	10	Y2+	PAIR3+
5	22	Yclk-	PAIR4-
18	9	Yclk+	PAIR4+
6	21	Y3-	PAIR5-

Full Configuration Up to an additional 2 Channel Link Chips			
Camera Connector	Right Angle Frame Grabber	Channel Link Signal	Cable Name
19	8	Y3+	PAIR5+
7	20	100 ohm	PAIR6+
20	7	terminated	PAIR6-
8	19	Z0-	PAIR7-
21	6	Z0+	PAIR7+
9	18	Z1-	PAIR8-
22	5	Z1+	PAIR8+
10	17	Z2-	PAIR9+
23	4	Z2+	PAIR9-
11	16	Zclk-	PAIR10-
24	3	Zclk+	PAIR10+
12	15	Z3-	PAIR11+
25	2	Z3+	PAIR11-
13	13	inner shield	Inner Shield
26	26	inner shield	Inner Shield

Unused pairs should be terminated in 100 ohms at both ends of the cable.

Table 5: DALSA Camera Control Configuration

Signal	Configuration	Pin
CC1	EXSYNC	9, 22
CC2	PRIN	10, 23
CC3	Spare	11, 24
CC4	Spare	12, 25

See Appendix A on page 61 for the complete DALSA Camera Link configuration table, and refer to the DALSA Web site, http://vfm.dalsa.com/docs/appnotes/00450-00_03-32_DALSA_Camera_Link_Road_Map.pdf, for the official Camera Link documents.

Camera Link Input Signals

The camera accepts control inputs through the Camera Link MDR26F connector. **All inputs are optional. The camera ships in exposure mode 2 (5kHz line rate and 100ms time). All Camera Control (CCx) signals are in a logic HIGH state.** Line rate can be set internally using the serial interface. Power-on rate is always 9600 baud.

The external control signals, EXSYNC and PRIN, are optional and enabled through the serial interface.

PRIN

PRIN is an optional input signal used for exposure control (PRIN).

PRIN	Indicates
High	Integration
Low	Pixel reset



IMPORTANT:
This camera uses the **falling edge** of EXSYNC to trigger line readout.

EXSYNC (Triggers Line Readout)

EXSYNC is an optional input signal that can be used to trigger the line readout rate. This camera uses the **falling edge of EXSYNC** to trigger line readout.

Note: EXSYNC should not be clocked faster than the camera's specified maximum line rate. The camera ignores the EXSYNC pulse until it has completed reading the last line out.

Camera Link Output Signals

These signals indicate when data is valid, allowing you to clock the data from the camera to your acquisition system. These signals are part of the Camera Link configuration and you should refer to the DALSA Camera Link Implementation Road Map, available at vfm.dalsa.com, for the standard location of these signals:

Clocking Signal	Indicates
LVAL (high)	Outputting valid line
DVAL (high)	Valid data
STROBE (rising edge)	Valid data



IMPORTANT: This camera's data should be sampled on the **rising edge of STROBE**.

Digital Data

The camera digitizes internally to 10 bits and outputs the most significant 8 bits in LVDS format on the Camera Link connector.

Test Pattern Pixels

To facilitate system-level debugging and verification of data path integrity, the camera can generate a test pattern. The test pattern is a ramp from 0 to 255DN, then starts at 0 again. Use the test pattern to verify the proper timing and connections between the camera and the frame grabber

2.2.2 Power Connector

Figure 4: Hirose 6-pin Circular Male Power Connector

Pin	Description	Pin	Description
1	+12V to +15V	4	GND
2	+12V to +15V	5	GND
3	+12V to +15V	6	GND

Hirose 6-pin Circular Male



The camera requires a single voltage input (+12V to +15V). The camera meets all performance specifications using standard switching power supplies, although well-regulated linear supplies provide optimum performance. See the Performance Specifications for current requirements.

When setting up the camera's power supplies follow these guidelines:

Protect the camera with a fast-blow fuse between power supply and camera.

Do not use the shield on a multi-conductor cable for ground.

Keep leads as short as possible to reduce voltage drop.



WARNING: It is extremely important that you apply the appropriate voltages to your camera. Incorrect voltages will damage the camera. Protect the camera with a fast-blow fuse between power supply and camera.

WARNING: The camera body should be electronically connected to the same ground potential as the negative terminal camera power supply.

Visit <http://vfm.dalsa.com> for a list of companies that make power supplies that meet the camera's requirements. The companies listed should not be considered the only choices. Many high quality supplies are available from other vendors. DALSA assumes no responsibility for the use of these supplies.

2.3 Timing

The camera has six different operating modes. The modes are set using the **sem** command. For complete details on setting exposure modes, refer to section 3.7 Setting Exposure Mode and Line Rate. 2.7.1 Timing: Exposure Mode 3, 4, and 5

2.3.1 Exposure Modes 3, 4, and 5

Figure 5. Exposure Mode 3, 4, and 5 Camera Link Timing

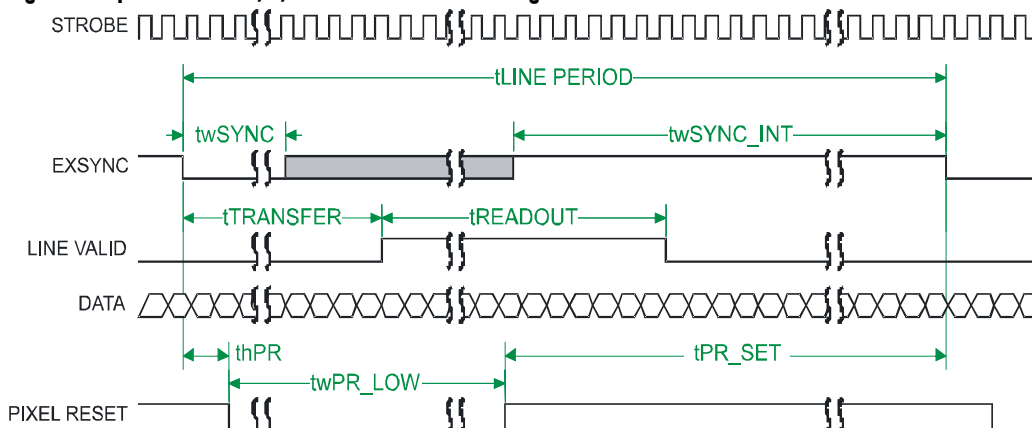


Table 6: Exposure Mode 3, 4 and 5 Timing Definitions

Symbol	Definition	Min (ns)	Max (ns)	Applies to Mode:		
				3	4	5
twSYNC	The minimum low width of the EXSYNC pulse when not in SMART EXSYNC mode.	100		x		x
twSYNC (SMART) *	The minimum low width of the EXSYNC pulse when in SMART EXSYNC modes to guarantee the photosites are reset.	4000			x	
twSYNC_INT	The minimum width of the high pulse when the "SMART EXSYNC" feature is turned off	100		x		x

Symbol	Definition	Min (ns)	Max (ns)	Applies to Mode:		
				3	4	5
twSYNC_INT (SMART) *	Is the integration time when the "SMART EXSYNC" feature is available and turned on. Note that the minimum time is necessary to guarantee proper operation.	3000			x	
tLINE PERIOD (t _{LP})	The minimum and maximum line times made up of tTransfer, tREADOUT plus tOVERHEAD to meet specifications.	50 000	200 000	x	x	x
tTransfer	The time from the reception of the falling edge of EXSYNC to the rising edge of LVAL when pretrigger is set to zero. Pretrigger reduces the number of clocks to the rising edge of LVAL but doesn't change the time to the first valid pixel. If the fixed integration time mode of operation is available and selected then the integration time is added to the specified value.	2400		x	x	x
tREADOUT	Is the number of pixels per tap times the readout clock period. Pretrigger = 0.	38400		x	x	x
thPR	Applies when the PRIN exposure control feature is enabled. The PRIN signal must be held a minimum time after the EXSYNC falling edge to avoid losing the integrated charge	1000				x
twPR_LOW	Minimum Low time to assure complete photosite reset	3000				x
tPR_SET	The nominal time that the photo sites are integrating. Clock synchronization will lead to integration time jitter, which is shown in the specification as +/- values. The user should command times greater than these to ensure proper charge transfer from the photosites. Failure to meet this requirement may result in blooming in the Horizontal Shift Register.	3000				x

*SMART EXSYNC refers to exposure mode 4. Refer to section 3.7 Setting Exposure Mode and Line Rate for further information on exposure modes.

2.3.2 Timing: Exposure Mode 6

Figure 6. Exposure Mode 6 Timing

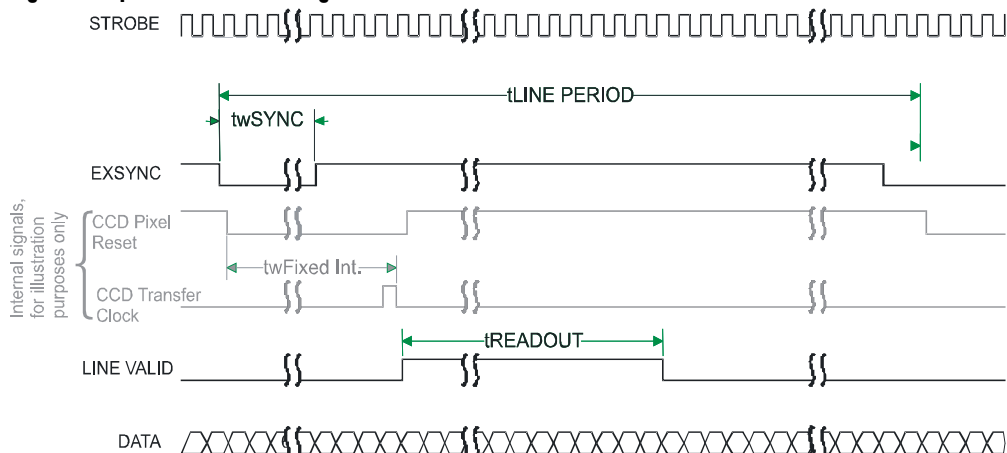


Table 7: Exposure Mode 6 Timing Definitions

Symbol	Definition	Min (ns)	Max (ns)
tw_{SYNC}	The minimum low width of the EXSYNC pulse.	100	
$t_{LINE PERIOD}$ (t_{LP})	The minimum and maximum line times made up of $t_{Transfer}$, $t_{READOUT}$ plus $t_{OVERHEAD}$ to meet specifications.	50 000	200 000
$tw_{Fixed Int.}$	Fixed Integration Time mode of operation for variable exsync frequency.	TBD	TBD
$t_{READOUT}$	Is the number of pixels per tap times the readout clock period. Pretrigger = 0.	38400	

2.4 Camera Link Serial Communication

Camera features can be controlled through the Camera Link™ serial communication (LVDS, 9600 baud). The serial interface uses simple ASCII-based protocol. See Appendix A for details on using the serial interface.

2.5 LED Status Indicator

Note: When more than one condition is active, the LED indicates condition with highest priority. Error and warning states are accompanied by corresponding messages further describing current camera status.

The camera is equipped with a red/green LED used to display the operational status of the camera. The following table summarizes the operating states of the camera and the corresponding LED states:

LED state	Priority	Camera Status	Condition
Blinking RED	1	Error	Fatal hardware failure
Blinking GREEN	3	Progress	Lengthy operation in progress
Steady GREEN	4	OK	Healthy

3

Software Interface: How to Control the Camera



This chapter outlines the more commonly used commands. See section B2 All Available Commands for a list of all available commands.

All camera features can be controlled through the serial interface. The camera can also be used without the serial interface after it has been set up correctly. Functions available include:

- Controlling basic camera functions such as gain and sync signal source
- Flat field correction commands
- Generating a test pattern for debugging

The serial interface uses a simple ASCII-based protocol and the camera does not require any custom software.

Online Help

For quick help, the camera can return all available commands and parameters through the serial interface. To generate this list, send the command **h** to the camera.

3.1 Retrieving Camera Settings

You can read current camera settings with the **gcp** command. The table below lists the settings displayed on the GCP Screen with sample values, along with a description of some of these settings:

GCP Screen		Description
GENERAL CAMERA SETTINGS		
Camera Model No.:	xxxxxxxxx	Camera model number.
Camera Serial No.:	xxxxxxxxx	Camera serial number.
Sensor Serial No.:	xxxxxxxxx	Sensor serial number.

GCP Screen		Description
Firmware Design Rev.:	xx-xx-xxxxx-xx	Firmware design revision number.
FPGA Design Rev.:	xxx.x	Displays the firmware design revision number.
Analog Gain (dB):	-0.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0 -0.0	Analog gain value of each output tap set with the sg or calculated with the ccp command. See section 3.10.2 Analog Signal Processing: Setting Analog Gain and Offset for details.
Analog Offset:	0 0 0 0 0 0 0 0	Analog offset value set with the sao or calculated with the ccf command. See section 3.10.2 Analog Signal Processing: Setting Analog Gain and Offset for details.
Digital Offset:	0 0 0 0 0 0 0 0	Digital offset value set with the sdo command. See section 3.10.4 Digital Signal Processing for details.
System Gain:	0 0 0 0 0 0 0 0	Digital gain value set with the ssg command. See section 3.10.4 Digital Signal Processing for details.
Background Subtract:	0 0 0 0 0 0 0 0	Background subtract value set with the ssb command. See section 3.10.4 Digital Signal Processing for details.
Pretrigger:	0	Pretrigger value set with the sp command. See section 3.13 Setting the Pre-trigger for details.
Number of Line Samples:	256	Number of lines samples set with the css command. See section 3.9 Returning Video Information for details.
Video Mode:	0	Current video mode value set with the svm command. See section f or details.
Exposure Mode:	2	Current exposure mode value set with the sem command. See section 3.7 Setting Exposure Mode and Line Rate for details.
SYNC Frequency:	5000.50 Hz	Current line rate. Value is

GCP Screen		Description
Exposure Time:	99.99 uSec	set with the ssf command. See section 3.7 Setting Exposure Mode and Line Rate for details. Current exposure time setting. Value is set with the set command. See section 3.7 Setting Exposure Mode and Line Rate for details.
FPN Coefficients:	off	States whether the fpn coefficients are turned on or off. Set using the epc command. See section 3.10.4 Digital Signal Processing for details.
PRNU Coefficients	off	States whether the prnu coefficients are turned on or off. Set using the epc command. See section 3.10.4 Digital Signal Processing for details.
Pixel Coefficients Set Loaded:	1	States which set of pixel coefficients are currently active (either 1 or 2). See section 3.5 Saving and Restoring Settings for details.
Upper Threshold:	240	Upper threshold value set with the sut command. See section for details.
Lower Threshold:	15	Lower threshold value set with the slt command. See section for details.
Region of Interest:	0001-12288	Region of interest size set with the roi command. See section 3.8 Setting a Region of Interest for details.

3.2 Communications Protocol Overview

Serial Protocol Defaults

- 8 data bits
- 1 stop bit
- No parity
- No flow control
- 9.6Kbps
- Camera does not echo characters

When entering commands, remember that:

- A carriage return (CR) ends each command. The linefeed character is ignored.
- The camera will answer each command with either "OK >" or "Error x: Error Message >". The ">" is always the last character sent by the camera.
- The following parameters are used throughout the manual:

i = integer
f = float
t = tap
[] = optional parameter

3.3 Camera Setup

The following steps describe how to begin using the GoldenEye commands:

1. If you have not already set up your camera cables, connect your cables as described in section 2.1.
2. Using a terminal program (e.g., Microsoft HyperTerminal), open a terminal window.

Note: In order to communicate with the camera, a serial connection in the Camera Link cable needs to be established. The framegrabber manufacturers should be able to provide a solution in order to communicate through this serial link. The terminal software can be also provided by the framegrabber manufacturer. Standard terminal software such as HyperTerminal can be used in case if COM port is allocated by the framegrabber.

Terminal should be set at 9600 baud during the camera power up.

3. When the terminal window is set up, power on the camera.
4. The boot-up message should appear on the terminal window:

Camera Initialization in progress, Please Wait ...

OK>

You can now communicate with the camera through the terminal using the software commands described in this manual.



5. Set up the framegrabber to receive the data. Following the framegrabber manufacturer's instructions, set up the parameters described in the **A1 Camera Link™ Configuration** Table on page 62.
6. Once the framegrabber is set up for data processing and the camera is powered up, run your image processing software. You should be able to see an image from the camera when exposed to a light source.
7. You can now set the other camera parameters described in this chapter.

3.4 Startup

When the camera is first started, it must perform several actions before it is ready for imaging. This startup routine takes approximately 15 seconds, and follows this sequence:

1. Initializes the camera and all internal hardware.

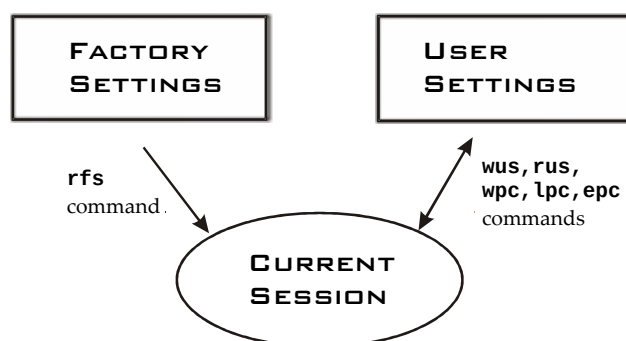
2. Loads the last settings saved to non-volatile memory, including the last set of video correction coefficients, if previously saved.
3. Restores user settings if previously saved, otherwise factory settings.
4. Performs a memory test and voltage test and reports an error if any occurred.

After this startup sequence is complete, the camera will return either the prompt "OK>" if no error occurred, or an error code if a problem has been discovered.

3.5 Saving and Restoring Settings

As illustrated in Figure 7, there are three type of camera settings: factory settings, user settings, and current session settings.

Figure 7: Saving and Restoring Overview



Factory Settings

On first initialization, the camera operates using the factory settings. You can restore the original factory settings at any time using the command **rfs**.

User Settings

You can save or restore your user settings to non-volatile memory using the following commands. Pixel coefficients are stored separately from all other parameters.

- To save all current user settings to EEROM, use the command **wus**. The camera will automatically restore the saved user settings when powered up.
- To restore the last saved user settings, use the command **rus**.
- To save the current pixel coefficients and **epc** settings, use the command **wpc [i]**. The optional parameter allows you to save more than one set of coefficients where:
 - 1** = Coefficient set one
 - 2** = Coefficient set two
 If a coefficient set is not specified, coefficients are saved as set one. Refer to page 43 for more information on the **epc** command.
- To restore the last saved pixel coefficients, use the command **lpc [i]**. The optional parameter is the coefficients set to load where:
 - 1** = Coefficient set one

2 = Coefficient set two

If a coefficient set is not specified, coefficient set one is loaded.

Current Session Settings

These are the current operating settings of your camera. These settings are stored in the camera's volatile memory and will not be restored once you power down your camera. To save these settings to non-volatile memory, use the command **wus**.

3.6 Setting Baud Rate

To set the speed of the camera serial communication port, use the command:

Purpose:	Sets the speed in bps of the serial communication port.
Syntax:	sbr i
Syntax Elements:	i
	Baud rate. Available baud rates are: 9600 (Default), 19200 , 57600 , and 115200 .
Notes:	- Power-on rate is always 9600 baud. - The rc (reset camera) command will <i>not</i> reset the camera to the power-on baud rate.
Example:	sbr 57600

3.7 Setting Exposure Mode and Line Rate

You have a choice of operating in one of six exposure modes. The table below outlines each exposure mode and is followed by instructions on how to change the exposure mode and line rate.

Table 8: Exposure Modes

Mode	Programmable Line Rate		Programmable Exposure Time		Description
	SYNC	PRIN	↓	↓	
2	Internal	Internal	Yes	Yes	Internal frame rate and exposure time. Factory setting.
3	External	Internal	No	No	Maximum exposure time
4	External	Internal	No	No	Smart EXSYNC
5	External	External	No	No	External sync, external pixel reset
6	External	Internal	No	Yes	Fixed integration time
7	Internal	Internal	Yes	No	Internal line rate, maximum exposure time

- To obtain the current value of the exposure mode, use the command **gcp**.
- When setting the camera to external signal modes, EXSYNC and/or PRIN must be supplied.

Setting Line Rate and Exposure Time

The camera's line rate (synchronization) is generated internally through the software command **ssf** when operating in modes 2 and 7, or set externally when operating in modes 3, 4, 5, and 6. To select how you want the camera's line rate to be generated:

1. You must first set the camera mode using the **sem** command. Refer to section 3.7.1 Setting the Exposure Mode for details.
2. Next, if using mode 2 or 7, use the command **ssf** to set the line rate and/or **set** (mode 2 or 6) to set the exposure time. Refer to section 3.6.2 Setting Line Rate and Exposure Time for details.

3.7.1 Setting the Exposure Mode

To set the exposure mode, use the command:

Purpose:	Sets the camera's exposure mode allowing you to control your sync, exposure time, and line rate generation.
Syntax:	sem i
Syntax Elements:	i
	Exposure mode to use. Factory setting is 2.
Notes:	• Refer to Table 8 for a quick list of available modes or to the following sections for a more detailed explanation. • To obtain the current value of the exposure mode, use the command gcp.
Related Commands:	ssf
Example:	sem 3

Exposure Modes in Detail

Mode 2: Internally Programmable Line Rate and Exposure Time

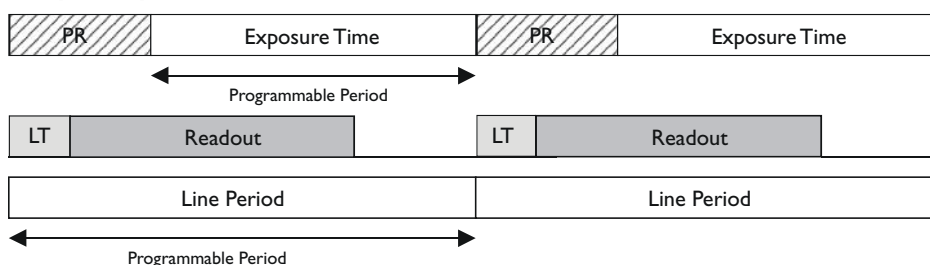
Mode 2 operates at a maximum line rate of 24kHz and exposure time of 1000.00 μ sec.

- When setting the line rate (using the **ssf** command), exposure time will be reduced, if necessary, to accommodate the new line rate. The exposure time will always be set to the maximum time (line period – line transfer time – pixel reset time) for that line rate when a new line rate requiring reduced exposure time is entered.
- When setting the exposure time (using the **set** command), line time will be increased, if necessary, to accommodate the exposure time. Under this condition, the line time will equal the exposure time + line transfer time.

LT = Line Transfer
Time

PR = Charge Reset

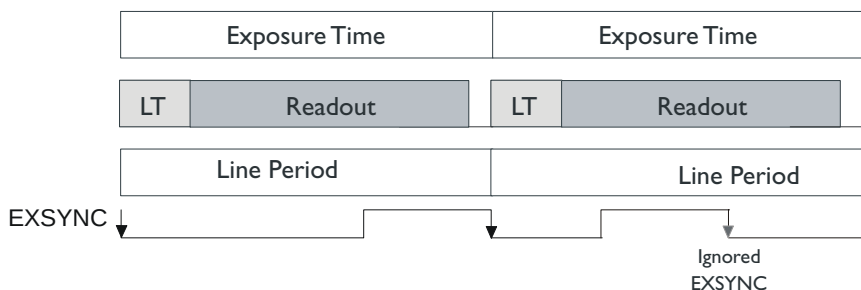
Example 1: Exposure Time less than Frame Period



Mode 3: External Trigger with Maximum Exposure

Line rate is set by the period of the external trigger pulses. Since there is no electronic shuttering, any trigger pulses faster than the read out time are ignored. The falling edge of the external trigger marks the beginning of the exposure.

Example 2: Frame Rate is set by External Trigger Pulses.



Mode 4: Smart EXSYNC, External Line Rate and Exposure Time

In this mode, EXSYNC sets both the line period and the exposure time. The falling edge of EXSYNC marks the beginning of the exposure and the rising edge ends the exposure and initiates line transfer.

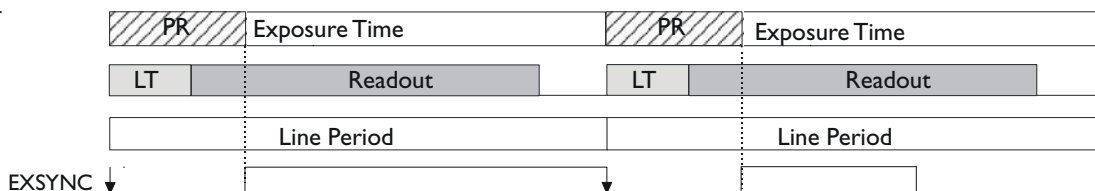
Restrictions:

If the falling edge of the EXSYNC signal occurs during the line transfer stage and/or readout, the pulse is ignored.

Example 3: Trigger Period is Repetitive and Greater than Read Out Time.

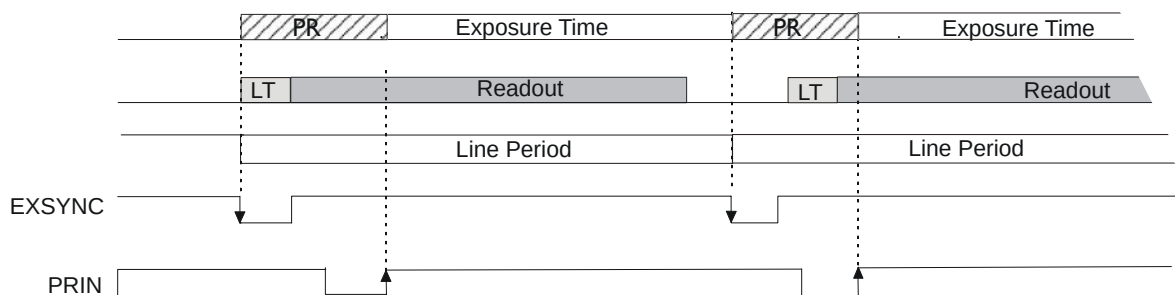
LT = Line Transfer
Time

PR = Pixel Reset



Mode 5: External Line Rate (EXSYNC) and External Pixel Reset (PRIN)

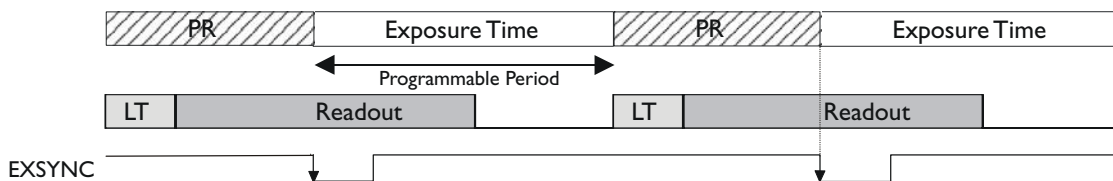
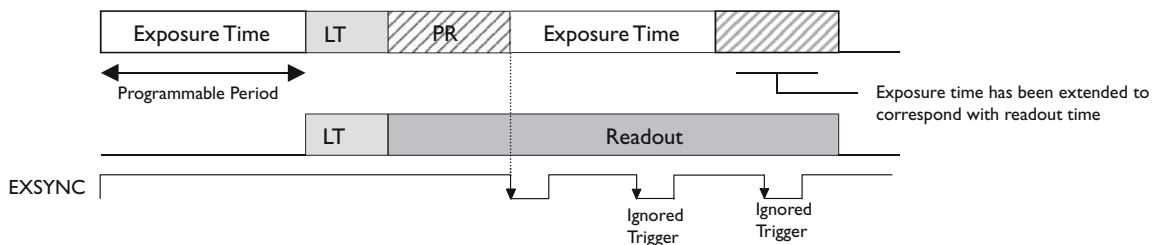
In this mode, the falling edge of EXSYNC sets the line period and the rising edge of PRIN sets the start of exposure time.

Figure 8: EXSYNC controls Line Period and PRIN controls Exposure Time

Mode 6: External Line Rate and Internal Exposure Time

This mode differs according to the trigger rate and the exposure time setting. However, the following rules apply to any condition:

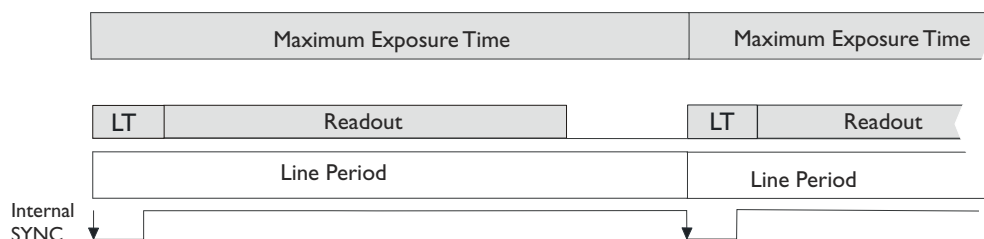
- Any additional EXSYNC triggers occurring during the exposure time will be ignored.
- All non-ignored EXSYNC triggers will start exposure and at the end of the programmed time (value set with the **set** command), readout begins. At the start of readout, the photosites are held in reset until the next EXSYNC falling edge.
- At the end of the exposure time, the collected data will be transferred to the readout area **only** if it is **not** already in the process of reading out. If readout is already in process, the exposure time will be extended until the readout is finished, as is illustrated in Example 5.

Example 4: Trigger Period is Repetitive and Greater than Read Out Time**Example 5: Trigger period is Nonreptitive and Occasionally Shorter than Read Out Time**

Mode 7: Internal Line Rate, Maximum Exposure Time

In this mode, the line rate is set internally with a maximum exposure time.

Figure 9: Mode 7 Camera Timing



3.7.2 Setting Line Rate and Exposure Time



Applies to Modes 2 and 7

Setting Line Rate

To set the line rate, use the command:

Purpose:	Sets the camera's line rate in Hz. Camera must be operating in exposure mode 2 or 7.
Syntax:	ssf f
Syntax Elements:	i
Notes:	Desired line rate in Hz. Allowable values are 5000 to 24000. - To read the current line frequency, use the command gcp. - If you enter an invalid line rate frequency, an error message is returned.
Related Commands:	sem
Example:	ssf 10000

Setting Exposure Time

Camera must be operating in exposure mode 2 or mode 6. The following table lists exposure mode time limits.

Table 9: Exposure Mode Time Ranges

Mode	Exposure Time Range
2	Fixed by ssf command
6	Limited by current frame rate (EXSYNC frequency)

To set the camera exposure time, use the command:

Purpose:	Sets the camera's exposure time in μ secs. Camera must be operating in exposure mode 2 or 6.
Syntax:	set f
Syntax Elements:	f
Notes:	Floating point number in μsecs. Allowable range is 3.00-1000.00 μsecs. To read the current line rate frequency, use the command gcp.

- If you enter an invalid exposure time, the valid range of values will be displayed.
- Related Commands: **sem, ssf**
- Example: **set 550.3**

3.8 Setting a Region of Interest

The **roi** command sets the pixel range affected by the **cag, cao, gl, gla**, and **ccp** commands. Pixels outside the specified region of interest will remain unaffected by these commands.

To define a region of interest, use the command:

- Purpose: Sets the region of pixels used in the **cag, cao, gl, gla**, and **ccp** commands.
- In most applications, the field of view exceeds the required object size and these extraneous areas should be ignored. It is recommended that you set the region of interest a few pixels inside the actual useable image.
- Syntax: **roi x1 x2**
- Syntax Elements: **x1**
- Pixel start number in a range from **1** to **12287**
- x2**
- Pixel end number in a range from **(x1 + 1)** to **12288**
- Related Commands
- **cag, cao, ccp** (see section 3.10.2 Analog Signal Processing: Setting Analog Gain and Offset and 3.10.4 Digital Signal Processing for details on these commands)
 - **gl, gla** (see section 3.9 Returning Video Information for details on these commands)
- Example: **roi 11 50**

3.9 Returning Video Information

The camera's microcontroller has the ability to read video data. This functionality can be used to verify camera operation and to perform basic testing without having to connect the camera to a framegrabber.

Returning a Single Line of Video

To return a single line of video, use the command:

Purpose: Returns a complete line of video (without digital processing or test pattern) displaying one pixel value after another. It also displays the minimum, maximum, and mean value of the line sampled within the region of interest (the region of interest command is explained in section 3.8 Setting a Region of Interest).

Use the **gl** command, or the following **gl a** command, to ensure the proper video input range into the processing chain before executing any pixel calibration commands.

Syntax: **gl [x1] [x2]**

Syntax Elements: **[x1]**

Optional parameter. This sets the start pixel to display on screen. Allowable range is **1** to **12288**. This parameter does not affect the Min, Max, and Mean statistics generated at the end of the line output.

[x2]

Optional parameter. This sets the end pixel to display on screen. Allowable range is **(x1 + 1)** to **12288**. This parameter does not affect the Min, Max, and Mean statistics generated at the end of the line output.

- Notes:**
- If you do not specify a pixel range to display, the line output will display all sensor pixels within the region of interest. The region of interest (**roi**) command is described on page 26.
 - Values returned are in DN and are 10 bit.

Example: **gl 10 200**

Returning Multiple Lines of Video

You can also return the average for multiple lines of video data. The number of lines to sample is set and adjusted by the **css** command. The camera displays the Min., Max., and Mean statistics.

To set the number of lines to sample, use the command:

Purpose:	Sets the number of lines to sample when using the gla command or for pixel coefficient calculations.
Syntax:	css i
Syntax Elements:	i Number of lines to sample. Allowable values are 256, 512 or 1024.
Notes:	To return the current setting, use the gcp command.
Example:	css 256

To return the average of multiple lines of video, use the command:

Purpose:	Returns the average for multiple lines of video data. The number of lines to sample is set and adjusted by the css command. The camera displays the Min., Max., and Mean statistics for the pixels in the region of interest (the region of interest command is explained in section 3.8 Setting a Region of Interest).
Syntax:	gla [x1] [x2]
Syntax Elements:	[x1] Optional parameter. This sets the start pixel to display on screen. Allowable range is 1 to 12288. This value does not affect the Min, Max, and Mean statistics generated at the end of the line output. [x2] Optional parameter. This sets the end pixel to display on screen. Allowable range is (x1 + 1) to 12288. This value does not affect the Min, Max, and Mean statistics generated at the end of the line output.
Notes:	- If you do not specify a pixel range to display, the line output will display all sensor pixels within the region of interest. The region of interest (roi) command is described on page 26. - Values returned are in DN and are 10 bit.
Example:	gla 10 200

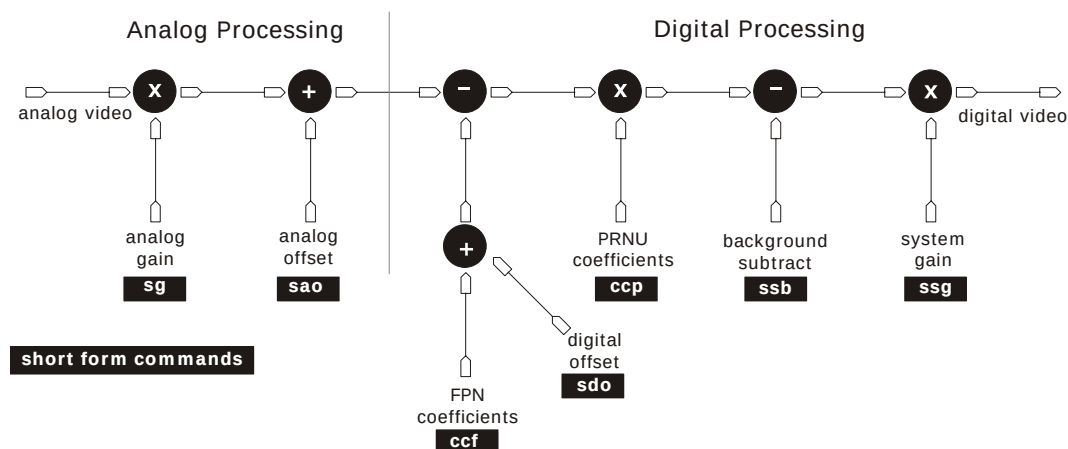
3.10 Analog and Digital Signal Processing Chain

3.10.1 Processing Chain Overview and Description

The following diagram shows a simplified block diagram of the camera's analog and digital processing chain. The analog processing chain begins with an analog gain adjustment, followed by an analog offset adjustment. These adjustments are applied to the video analog signal prior to its digitization by an A/D converter. The digital

processing chain contains the FPN correction, the PRNU correction, the background subtract, and the digital gain (system gain) and offset. All of these elements are user programmable.

Figure 10: Signal Processing Chain



Analog Processing

Optimizing offset performance and gain in the analog domain allows you to achieve a better signal-to-noise ratio (dynamic range) than you would achieve by trying to optimize the gain and offset in the digital domain. As a result, perform all analog adjustments prior to any digital adjustments. All analog commands are described in section 3.10.2 Analog Signal Processing: Setting Analog Gain and Offset.

1. Analog gain is multiplied by the analog signal to increase the signal strength before the A/D conversion. It is used to take advantage of the full dynamic range of the A/D converter. For example, in a low light situation the brightest part of the image may be consistently coming in at only 50% of the DN. An analog gain of 6 dB (2x) will ensure full use of the dynamic range of the A/D converter.
2. The offset or black level is an “artificial” offset introduced into the video path to ensure that the A/D is functioning properly, the black level clamping algorithm functions, and that FPN coefficients are calculated correctly. This analog offset should be set so that it is at least 3 times the rms noise value at the current gain. If you wish to maximize the available output swing under low gain settings, the **sao** command is provided to alter the offset. Additionally, if you are operating close to the maximum gain specification, it may be necessary to increase the offset. Automatic adjustment can be achieved using the **cao** command which adjusts the offset to achieve the specified target value.

Digital Processing

To optimize camera performance, digital signal processing should be completed after any analog adjustments.

1. Fixed pattern noise (FPN) calibration (calculated using the **ccf** command) is used to subtract away individual pixel dark current.
2. The digital offset (**sdo** command) is used to take away the analog offset in the digital domain. FPN calibration sets the digital offset to zero during calibration.

Alternatively, if you are not using FPN calibration, you can set the **sdo** value to user defined value before performing PRNU calibration.

3. Photo-Response Non-Uniformity (PRNU) coefficients are used to correct the difference in responsivity of individual pixels (i.e. given the same amount of light different pixels will charge up at different rates) and the change in light intensity across the image either because of the light source or due to optical aberrations (e.g. there may be more light in the center of the image).
4. Background subtract (**ssb** command) and system (digital) gain (**ssg** command) are used to increase image contrast after FPN and PRNU calibration.

The following sections are organized as follows:

1. Section 3.10.2 Analog Signal Processing: Setting Analog Gain and Offset provides a detailed description of all analog processing chain commands.
2. Section 3.10.3 Calibrating the Camera to Remove Non-Uniformity (Flat Field Correction) provides a description on how to perform flat field calibration.
3. Section 3.10.4 Digital Signal Processing provides a detailed description of all digital processing chain commands.

3.10.2 Analog Signal Processing: Setting Analog Gain and Offset

Optimizing offset performance and gain in the analog domain allows you to achieve a better signal-to-noise ratio (dynamic range) than you would achieve by trying to optimize the gain and offset in the digital domain. As a result, perform all analog adjustments prior to any digital adjustments.

Setting Analog Offset

To set the analog offset of the camera, use the command:

Purpose:	Sets the analog offset.
Syntax:	sao t i
Syntax Elements:	t Tap selection. Allowable range is 1 to 8, or 0 for all taps. i Analog offset value in DN. Allowable range is 0 to 1023.
Notes:	- The offset increases linearly with higher values. A value of 100 does not equal an offset of 100DN. - The resulting analog offset value depends on other camera parameters such as temperature, line rate, and gain.
Example:	sao 0 200

Setting Analog Gain

To set the analog gain portion of the camera, use the command:

Purpose:	Sets the camera's analog gain value. Analog gain is multiplied by the analog signal to increase the signal strength before the A/D conversion. It is used to take advantage of the full dynamic range of the A/D converter.
Syntax:	sg t i
Syntax Elements:	t Tap value. Use 0 for all taps or 1 to 8 for individual tap selection. f Gain setting. Allowable range is -10 to 10dB. For nominal gain, set to 0.
Example:	sg 0 2.2

Calibrating Analog Offset and Analog Gain Values

Instead of manually setting the analog offset to a specific value, you can have the camera determine the offset value by providing the camera with a peak target value to achieve.

Calibrating Analog Offset

Perform analog offset calibration before applying dark calibration. Refer to FPN (Dark) Calibration on page 39 for more information on performing dark calibration.

To calibrate the analog offset:

Purpose:	Instead of manually setting the analog offset to a specific value, you can have the camera determine the offset values by providing the camera with a target value to achieve. This command calculates each tap's pixels within the ROI to the specified peak target value.
Syntax:	cao t i
Syntax Elements:	t Tap selection. Allowable range is 1 to 8, or 0 for all taps. i Peak target value in a range from 1 to 400DN.
Notes:	See section 3.9 Returning Video Information for more information on line averages
Related Commands:	gla, gl
Example:	cag 1 156

Calibrating Analog Gain to a Target Value

Perform analog gain calibration before applying white light calibration. Refer to PRNU (White Light) Calibration on page 39 for more information on performing white light calibration.

To calibrate the analog gain, use the command:

Purpose:	Instead of manually setting the analog gain to a specific value, you can have the camera determine the gain values by providing the camera with a target value to achieve. The following diagrams summarize and provide an example of how analog gain is calibrated when using a region of interest.
Syntax:	cag t i
Syntax Elements:	t Tap value. Use 0 for all taps or 1 to 8 for individual tap selection. i Peak target value in a range from 256 to 1004DN. 6.25 % of the pixels within the tap that are within the ROI, should be higher than the target threshold.
Notes:	- Calibration is done on raw data only. All digital processing and pixel coefficients are temporarily disabled during calibration. - See section 3.9 Returning Video Information for more information on line averages - This function requires constant light input while executing. - Refer to section 3.8 Setting a Region of Interest for more information on using a region of interest.
Example:	cag 0 155

Calibrate Analog Gain to Calculated Peak Value

Purpose:	Instead of manually setting the analog gain to a specific value, the camera can determine appropriate gain values. This command calculates and sets the analog gain according to the algorithm determined by the first parameter.
Syntax:	ccg i t i
Syntax Elements:	i Calibration algorithm to use. 1 = This algorithm adjusts analog gain so that 8% to 13% of tap ROI pixels are above the specified target value. 2 = This algorithm adjusts analog gain so that the average pixel value in tap's ROI is within 97 to 99% of the specified target value. This algorithm is more repeatable than algorithm 1 but may be slower in some cases. t Tap value. Use 0 for all taps or 1 to 8 for individual tap selection. i Calculation target value in a range from 1024 to 4055DN (12 bit LSB).
Notes:	• This function requires constant light input while executing. • If very few tap pixels are within the ROI, gain calculation may not be optimal. • When all taps are selected, taps outside of the ROI are set to the average gain of the taps that are within the ROI. • Perform analog gain algorithms before performing FPN and PRNU calibration. • All digital settings affect the analog gain calibration. If you do not want the digital processing to have any effect on the camera gain calibration, then turn off all digital settings by sending the commands: sdo 0 0, epc 0 0, ssb 0 0, and ssg 0 4096. Digital settings are automatically turned off if you are using algorithm 1.
Example:	ccg 2 0 3040
Related Commands:	sag , ssg

Figure 11: Calibrating Analog Gain for a Tap outside of the Region of Interest

In the following example, analog gain is being set for a tap outside the region of interest. Since analog gain cannot be set for taps outside the region of interest, an error message is returned and calibration does not occur. Note: Both the tap and its interleaved partner (for example tap 1 and 2) must be outside of the region of interest for this condition to occur.

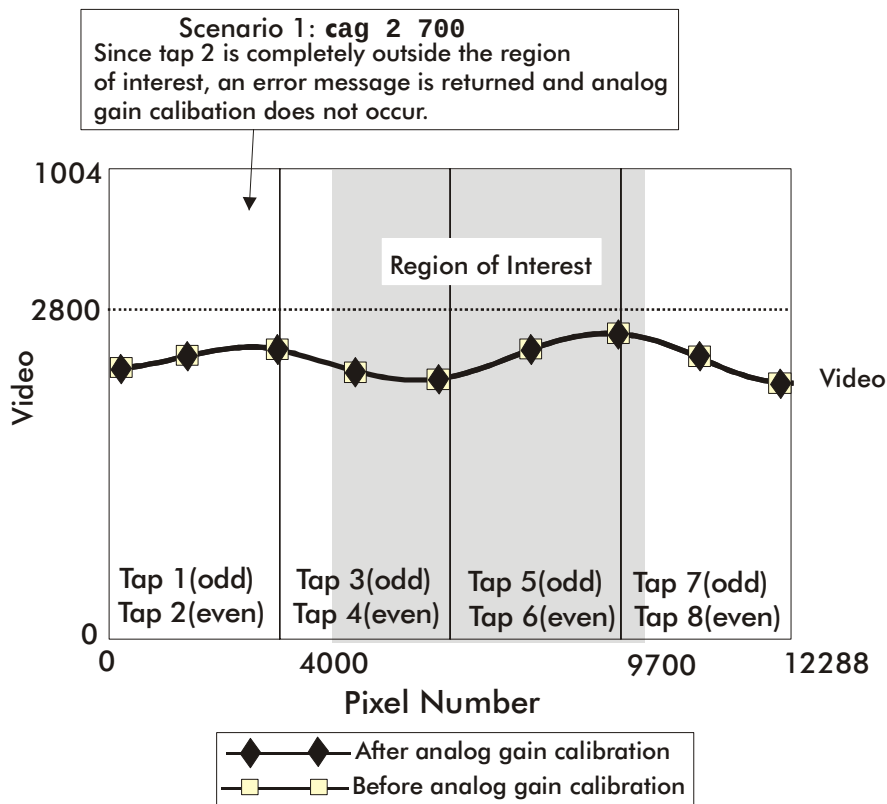


Figure 12: Calibrating Analog Gain for a Tap inside the Region of Interest

In the following example, analog gain is being set for a tap inside the region of interest. The peak value of the tap is calibrated to the specified target value and all other taps remain unchanged.

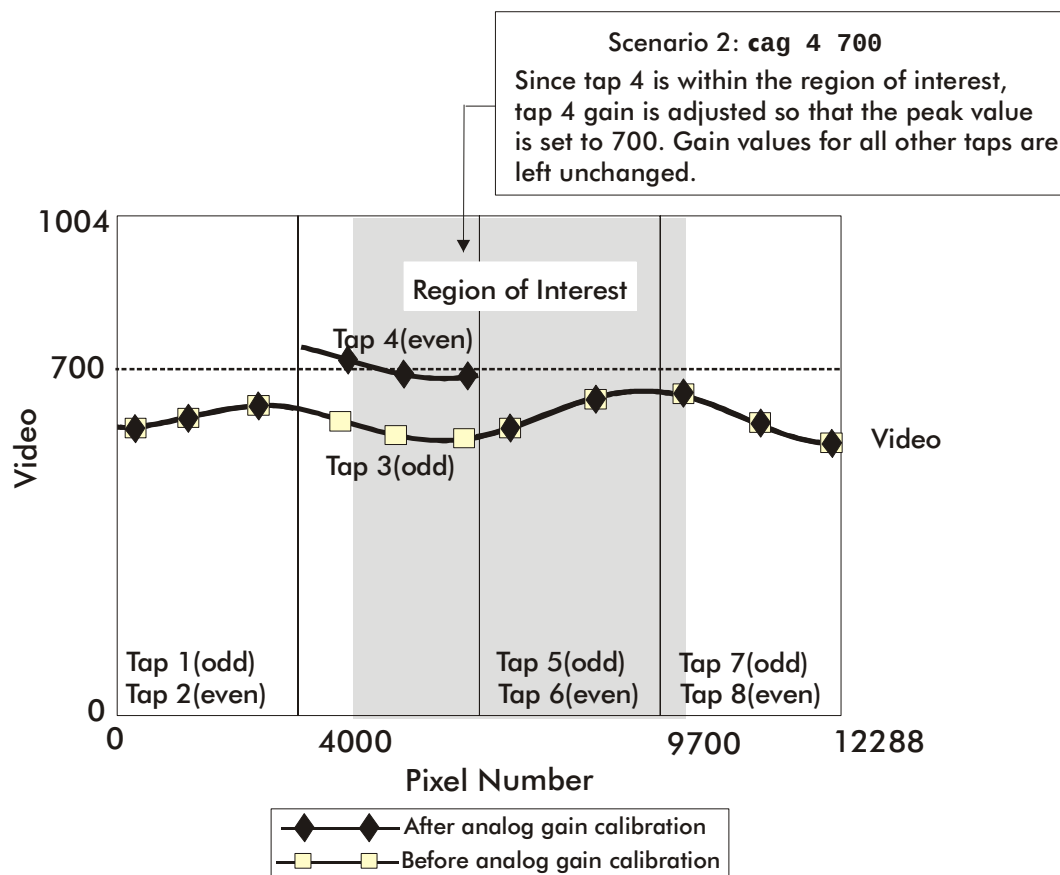
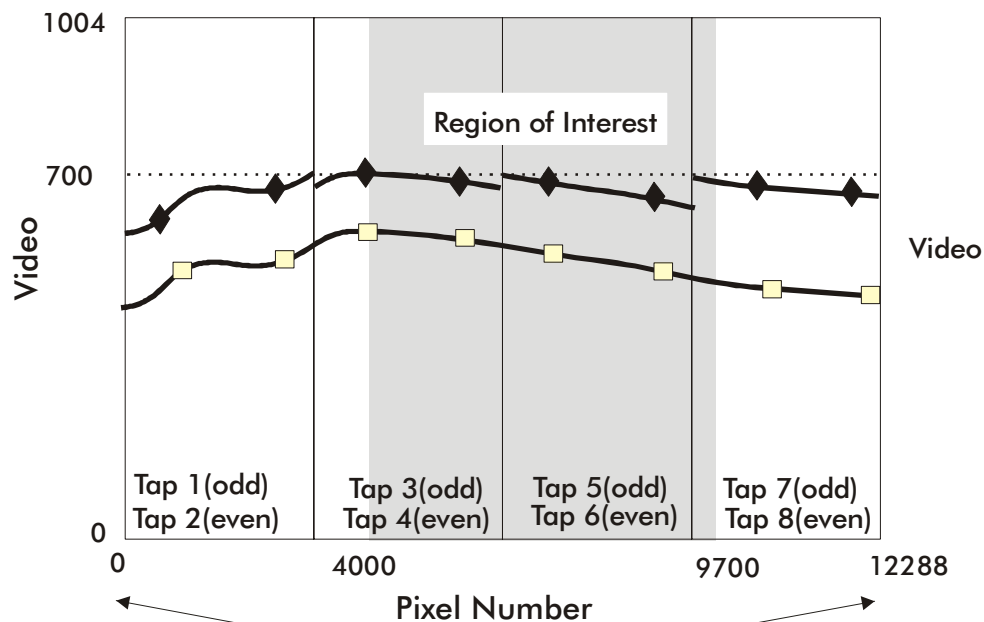
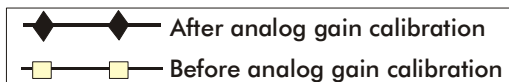


Figure 13: Calibrating Analog Gain for all Taps

In the following example, analog gain is being set for all taps. The peak value of each tap within the region of interest is calibrated to the specified target value. All taps completely outside the region of interest are calibrated to the average analog gain value of the taps inside the region of interest.

**Scenario 3: `cag 0 700`**

When calibrating all taps, taps completely outside the region of interest (in this example, interleaved taps 1 and 2) are calibrated to the average analog gain of taps within the region of interest. Taps within the region of interest calibrate to the target value. Note: Seams between taps will be visible until you perform white light calibration using the `ccp` command.



3.10.3 Calibrating the Camera to Remove Non-Uniformity (Flat Field Correction)

The camera has the ability to calibrate itself in order to remove non-uniformity in the image. This video correction operates on a pixel-by-pixel basis and implements a two point correction for each pixel. This correction can reduce or eliminate image distortion caused by the following factors:

- Fixed Pattern Noise (FPN)
- Photo Response Non Uniformity (PRNU)
- Lens and light source non-uniformity

The two point correction is implemented such that for each pixel:

$$V_{\text{output}} = (V_{\text{input}} - \text{FPN}(\text{pixel}) - \text{digital offset}) * \text{PRNU}(\text{pixel})$$

where	V_{output}	=	digital output pixel value
	V_{input}	=	digital input pixel value from the CCD
	$\text{PRNU}(\text{pixel})$	=	PRNU correction coefficient for this pixel
	$\text{FPN}(\text{pixel})$	=	FPN correction coefficient for this pixel

The calibration algorithm is performed in two steps. The fixed offset (FPN) is determined first by performing a calibration without any light. This calibration determines exactly how much offset to subtract per pixel in order to obtain flat output when the CCD is not exposed. Digital offset is set to zero during FPN calibration.

The white light calibration is performed next to determine the multiplication factors required to bring each pixel to the required value (balance target) for flat, white output. Video output is set slightly above the brightest pixel (depending on offset subtracted).

For FPN (dark light) the value of all pixels should be between 1DN and 100DN (8-bit). For PRNU (white light) the recommended value is between 64DN and 251DN (8-bit). Use the **gl** command to ensure the proper input to the digital processing, V_{input} .

White light calibration will gain up to maximum white light pixel plus the maximum FPN subtract pixel.

When performing any camera calibration, random noise is minimized by averaging out up to 64 lines of valid data. To adjust the sample line size, use the **css i** command, where **i** is 256, 512, 1024 (factory setting). A lower value reduces the camera's calibration time, at the expense of increased coefficient error.

Calibration Steps Overview

1. Set up the camera operating environment (i.e. line rate, exposure, etc.)
2. Perform all analog and digital adjustments.
3. Make sure there are suitable calibration targets. The target to calibrate should be a flat field, e.g. plastic or ceramic for white calibration.

4. Set the calibration sample size using the command **css** (see Returning Multiple Lines of Video page 29).
5. Perform Dark (FPN) calibration (see FPN (Dark) Calibration on page 39).
6. Perform White (PRNU) calibration (see PRNU (White Light) Calibration on page 39).
7. Save settings and pixel coefficients using the commands **wus** and **wpc**. See section 3.5 Saving and Restoring Settings for details.

Note: It is important to do the FPN calibration first. Results of the FPN calibration are used in the PRNU procedure. We recommend that you repeat the calibration when a temperature change greater than 10°C occurs.

FPN (Dark) Calibration Overview

Dark calibration is used to remove the fixed analog offset from the video path. It is recommended that you repeat the calibration when a temperature change greater than 10°C occurs. **Note:** Digital offset is set to zero during FPN calibration.

To perform FPN calibration:

1.	Stop all light from entering the camera. (Tip: cover lens with a lens cap.)
2.	Verify that output signal level is within range by issuing the command gl or gla (recommended range is 1-100). If the signal level is too low, adjust the analog offset (sao) or use the automated algorithm cao 0 i . If the signal level is too high, ensure that no light is entering the camera, reduce the analog offset or reduce the gain level (sg).
3.	Issue the command ccf [i] . The camera will respond with OK> if no error occurs. Dark calibration automatically calibrates FPN coefficients and resets digital offset to zero. Refer to Calibration Commands on page 45 for syntax and parameter details on the ccf command. Note: Digital offset values are reset to zero after sending the ccf command.
4.	After the calibration is complete, you can save these settings, and the PRNU coefficients, to non-volatile memory so they will be remembered after power-down. To do so, issue the commands wus and wpc i where i is the pixel coefficient set to save (either 1 or 2). These commands will save both the pixel coefficients and the epc (enable pixel coefficients) command setting. Refer to section 3.5 Saving and Restoring Settings for more information on the wus and wpc commands

PRNU (White Light) Calibration Overview

White light calibration is more complex than dark calibration because the camera attempts to create a flat white image. This calibration corrects PRNU effects as well as non-uniform lighting and lens vignetting affects.

White light calibration requires a clean, white reference. The quality of this reference is important for proper calibration. White paper is often not sufficient because the grain in the white paper will distort the correction. White plastic or white ceramic will lead to better balancing.

There are several restrictions that must be met in order for the calibration to succeed:

1. The camera is sufficiently sensitive to detect 60 Hz ambient light flicker which may affect camera performance and calibration results.
2. The light level should be set so that all pixels are between 64DN and 251DN for 8 bit data, otherwise a warning will be sent stating that the camera could not calibrate all pixels to the same level. Use the **gl** command to determine input level in a range from 256-1004 for 10 bit data. If the signal level is too low or too high, adjust analog gain using the command **sg**.
3. The variance in light intensity across the target must not be more than 4 to 1. Because the maximum per-pixel digital gain is 4x, the camera will not be able to compensate for extremely non-uniform light.

These restrictions are all tested within the calibration algorithm and the camera will report an informal message code if any of these conditions could not be met.

To perform a white light calibration:

1.	Place a white reference in front of the camera.
2.	Verify that output signal level is within range by issuing the command gl or gla (recommended range is 256-1004). If signal level is too low or too high, adjust the gain using the command sg Or use the automated algorithm cag 0 i . DALSA recommends a target value of about 80% of output swing. Refer to section Calibrating Analog Offset and Analog Gain Values on page 32 for more information on how the camera performs analog offset calibration.
3.	Instruct the camera to perform PRNU calibration using the command ccp [i] or cpa i t i command. The camera will respond with OK> if no error occurs. Refer to Calibration Commands on page 45 for syntax and parameter details on the ccf and cpa commands.
4.	After the calibration is complete, you can save these settings to non-volatile memory so they will be remembered after power-down. To do so, issue the command wpc .

Returning Calibration Results and Errors

After calibration, you can retrieve the results using the command **dpc**. This function returns all the pixel coefficients in the order FPN, PRNU, FPN, PRNU... The camera also returns the pixel number with each coefficient.

To set a range for the returned coefficients provide an optional pixel start and end value:

Example: display pixel coefficient from pixel 10 to 20

dpc 10 20

3.10.4 Digital Signal Processing

To optimize camera performance, digital signal processing should be completed after any analog adjustments.

Subtracting Background

To subtract the video scene offset or any other optical background from the output video signal, use the command:

Purpose:	Use the background subtract command after performing flat field correction if you want to improve your image in a low contrast scene. You should try to make your darkest pixel in the scene equal to zero.
Syntax	ssb t i
Syntax Elements:	t Tap selection. Allowable range is 1 to 8, or 0 for all taps. i Subtracted value in a range in DN from 0 to 768. Applies to 10 bit data.
Notes:	When subtracting a digital value from the digital video signal the output can no longer reach its maximum. Use the ssg command to correct for this. See the following section for details on the ssg command.
Related Commands	ssg
Example	ssb 0 500

Setting Digital Gain

To set the digital gain, use the command:

Purpose:	Improves signal output swing after a background subtract. When subtracting a digital value from the digital video signal, using the ssb command, the output can no longer reach its maximum. Use the this command to correct for this where:
	$\text{ssg value} = \frac{\text{max output value}}{\text{max output value} - \text{ssb value}}$
Syntax:	ssg t i
Syntax Elements:	t Tap value. Use 0 for all taps or 1-8 for individual tap selection. i 4096-16384. 4096 corresponds to low gain (1x). 16384 corresponds to high gain (4x).
Example:	ssg 0 10000

Setting Digital Offset

To subtract the A/D offset from the video signal, use the command:

Purpose:	Sets the digital offset. Use the digital offset command to reset the offset to zero if you perform PRNU calibration (ccp) without FPN calibration (ccf). Digital offset is reset to zero with the ccf command. See the Dark Calibration description on page 39 for more information on the ccf command.
Syntax:	sdo t i
Syntax Elements:	t Tap selection. Allowable range is 1 to 8, or 0 for all taps. i Subtracted offset value in a range from 0 to 511.
Notes:	When subtracting a digital value from the digital video signal, the output can no longer reach its maximum
Example:	sdo 0 100

Saving, Loading, Resetting, Enabling, and Disabling Pixel Coefficients

After pixel coefficients have been saved to non-volatile memory using the **wpc** command, you can reload them. This is useful when you have made unwanted changes to pixel coefficients.

To save the FPN and PRNU coefficients, use the command:

Purpose:	Saves the current pixel coefficients to non-volatile memory. The optional parameter allows you to save up to two sets of coefficients. If the optional parameter is not used, coefficients are written to set one.
Syntax:	wpc [i]
Syntax Elements:	[i] Coefficient set to save. 1 = Coefficient set one 2 = Coefficient set two
Related Commands:	lpc
Example:	wpc 2

To load the FPN and PRNU coefficients, use the command:

Purpose:	Loads the specified pixel coefficients to non-volatile memory. If the optional parameter is not used, then coefficient set one is loaded.
Syntax:	lpc [i]
Syntax Elements:	[i] Coefficient set to load. 1 = Coefficient set one 2 = Coefficient set two
Related Commands:	wpc
Example:	lpc 2

To reset pixel coefficients to zero, use the command:

Syntax:	rpc
---------	------------

To enable or disable PRNU and/or FPN coefficients, use the command:

Purpose:	Enables and disables FPN and PRNU coefficients.
Syntax:	epc i i [i]
Syntax Elements:	i FPN coefficients. 0 = FPN coefficients disabled 1 = FPN coefficients enabled i PRNU coefficients. 0 = PRNU coefficients disabled 1 = PRNU coefficients enabled [i] Optional parameter. Turns current digital offset setting on or off. 0 = Turn current digital offset setting off and set to zero 1 = Digital offset enabled and returned to previous setting
Notes:	• epc settings, except the optional parameter, are saved after issuing the wpc command • After turning off digital offset values, the gcp screen will still display previous digital offset values and will not be reset to zero.
Example:	epc 1 0 0

Setting and Reading a Pixel's PRNU and FPN Coefficient

You can set or read an individual pixel's PRNU and FPN coefficient

PRNU Coefficients

To set a PRNU coefficient, use the command:

Purpose:	Sets an individual pixel's PRNU coefficient.
Syntax:	spc <i>i i</i>
Syntax Elements:	<i>i</i>
	The pixel number from 1 to 12288.
	<i>i</i>
	Coefficient value in a range from 1 to 3071 where
	$PRNU = 1 + \frac{i}{1024}$
Example:	spc 10 50

To read the PRNU coefficient, use the command:

Purpose:	Returns a pixel's PRNU coefficient value in DN
Syntax:	gpc <i>i</i>
Syntax Elements:	<i>i</i>
	The pixel number to read in a range from 1 to 12288.
Example:	gpc 10

FPN Coefficients

To set the FPN coefficient, use the command:

Purpose:	Sets an individual pixel's FPN coefficient.
Syntax:	sfc <i>i i</i>
Syntax Elements:	<i>i</i>
	The pixel number from 1 to 12288.
	<i>i</i>
	Coefficient value in a range from 0 to 511.
Example:	sfc 10 50

To read the FPN coefficient, use the command:

Purpose: Returns a pixel's FPN coefficient value in DN (12-bit LSB)

Syntax: **gfc *i***

Syntax Elements: ***i***

The pixel number to read in a range from 1 to 12288.

Example: **gfc 10**

Calibration Commands

The camera has the ability to calibrate itself in order to remove non-uniformity in the image. For a complete description on how to use these commands, see section 3.10.3 Calibrating the Camera to Remove Non-Uniformity (Flat Field Correction).

FPN Calibration

To perform FPN calibration, use the command:

Syntax: Performs FPN calibration and eliminates FPN noise by subtracting away individual pixel dark current.

Syntax: **ccf [*i*]**

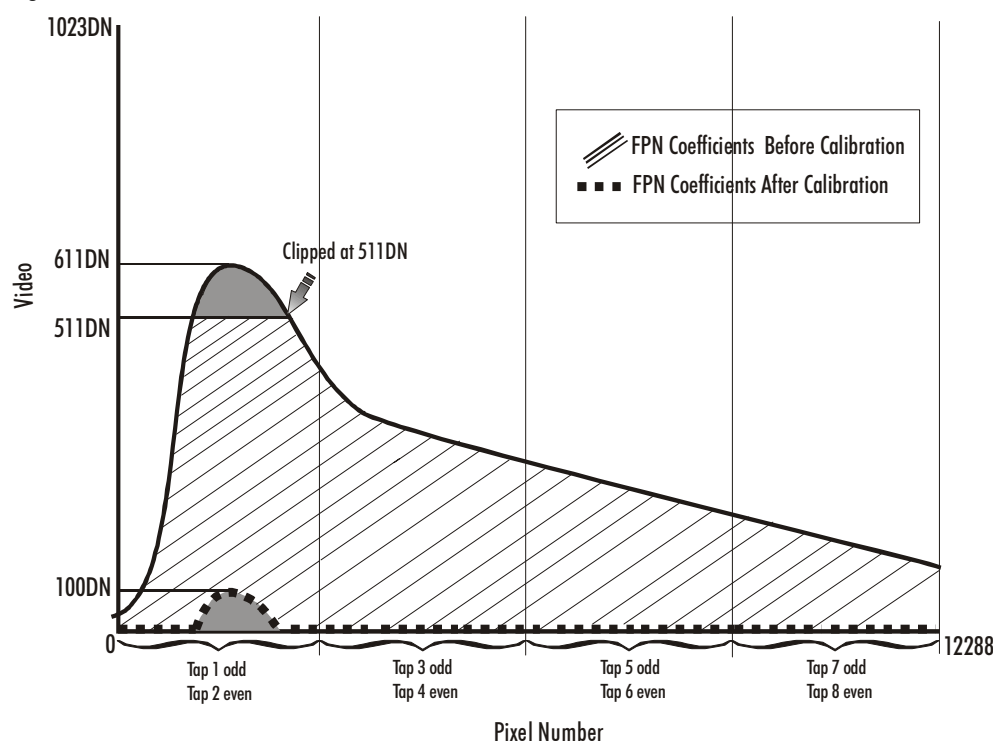
Syntax Elements: **[*i*]**

Optional parameter that sets the analog offset first to ***i*** before calculating the FPN coefficients range from 1 to 100DN for the specified region of interest. If value is left blank, current offset values are used. Dark calibration automatically calibrates FPN coefficients and digital offset.

- Notes
- Perform all analog and digital adjustments before calibrating FPN.
 - FPN calibration is not affected by the region of interest.
 - Calibrate FPN before calibrating PRNU.

Example: **ccf 10**

Figure 14: FPN Calibration



PRNU Calibration

To perform PRNU to a user entered value, use the command:

Purpose:	Performs PRNU calibration and eliminates the difference in responsivity between the most and least sensitive pixel creating a uniform response to light. Using this command, you must provide a calibration target.
Syntax:	cpa i i
Syntax Elements:	i

PRNU calibration algorithm to use:

1 = This algorithm first adjusts each tap's analog gain so that 8-13% of pixels within a tap are above the value specified in the target value parameter. PRNU calibration then occurs using the peak pixel in the region of interest.

2 = Calculates the PRNU coefficients using the entered target value as shown below:

$$\text{PRNU Coefficient}_i = \frac{\text{Target}}{(\text{AVG Pixel Value}_i) - (\text{FPN}_i + \text{sdo value})}$$

The calculation is performed for all sensor pixels but warnings are only applied to pixels in the region of interest. This algorithm is useful for achieving uniform output across multiple cameras. Recommended peak video output before PRNU calibration is 5-20% lower than target.

3 = This algorithm includes an analog gain adjustment prior to PRNU calibration. Analog gain is first adjusted so that the average pixel value in tap's ROI is within 97 to 99% of the specified target value. It then calculates the PRNU coefficients using the target value as shown below:

$$\text{PRNU Coefficient}_i = \frac{\text{Target}}{(\text{AVG Pixel Value}_i) - (\text{FPN}_i + \text{sdo value})}$$

The calculation is performed for all sensor pixels but warnings are only applied to pixels in the region of interest. This algorithm is useful for achieving uniform output across multiple cameras. Recommended peak video output before PRNU calibration is 5-20% lower than target.

i

Peak target value in a range from 256 to 1004DN. The target value must be greater than the current peak output value.

- Notes:
- Perform all analog and digital adjustments before calibrating PRNU.
 - This command performs the same function as the **cpp** command but forces you to enter a target value.
 - Calibrate FPN before calibrating PRNU. If you are not performing FPN calibration then issue the **rpc** (reset pixel coefficients) command and set the **sdo** (set digital offset) value so that the output is near zero under dark.

Example: **cpa 1 600**

To perform PRNU calibration to a camera calculated peak value, use the command:

Purpose: Performs PRNU calibration and eliminates the difference in responsivity between the most and least sensitive pixel creating a uniform response to light. Using this command, you do not have to provide a calibration target.

Syntax: **ccp [i]**

Syntax Elements: **[i]**

When the optional parameter is provided, each tap's analog gain so that 8-13% of pixels within a tap are above the value specified in the target value. This command sets the analog gain first to **i** before calculating the PRNU coefficients range from 256 to 1004DN. If value is left blank, current gain values are used.

- Notes:**
- This command performs the same function as the **cpa 1 i** command but does not force you to enter a target value.
 - Perform all analog and digital adjustments before calibrating PRNU.
 - Calibrate FPN before calibrating PRNU.

Example: **ccp**

Figure 15: PRNU Calibration (ROI=1-12288) (ccp 800 or cpa 1 800)

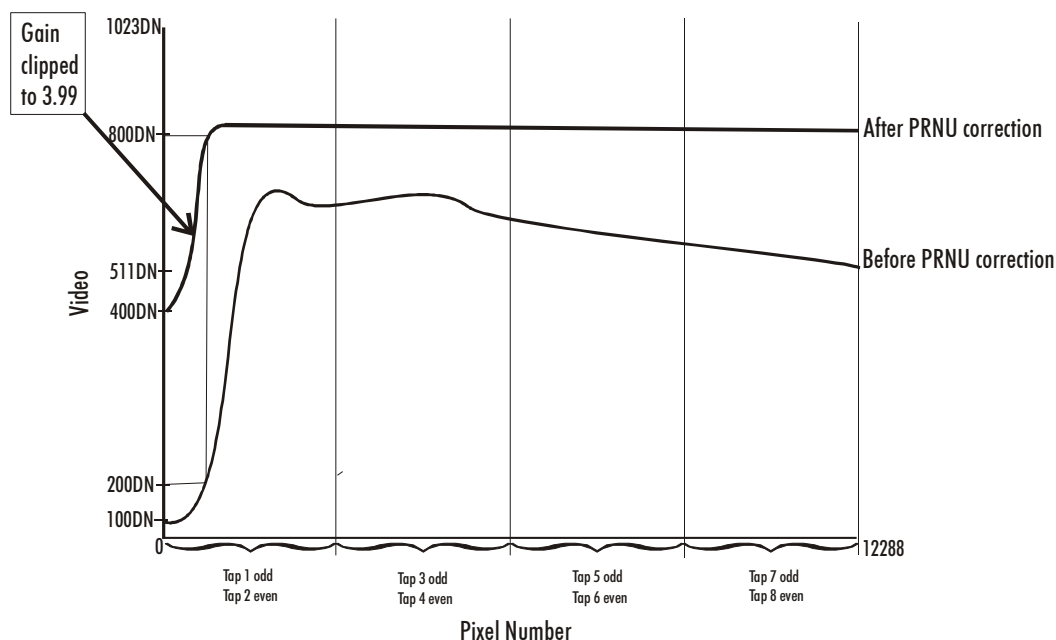
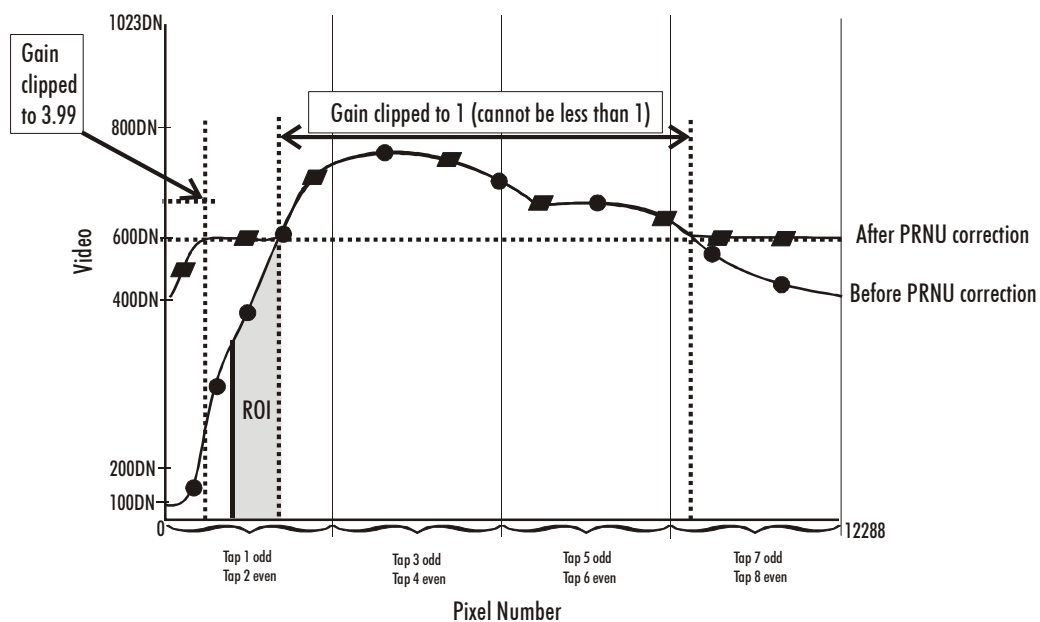
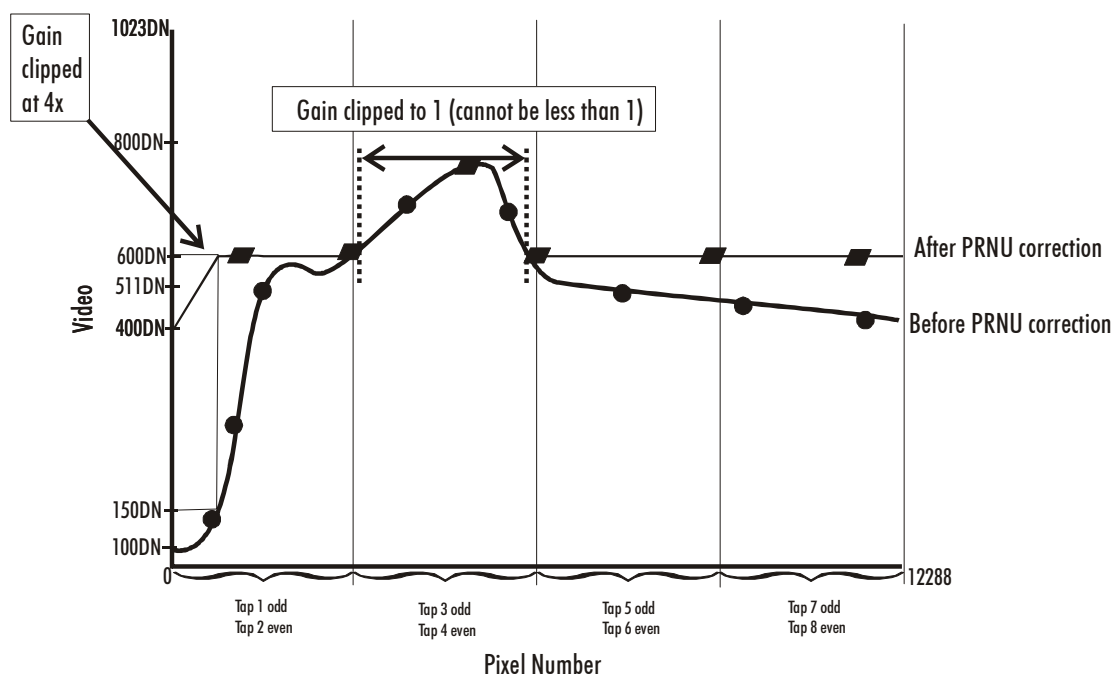


Figure 16: PRNU Calibration (ROI=1501-2000) (ccp 800 or cpa 1 800)**Figure 17: PRNU Calibration using a Peak Target Value (ROI=1-12288) (cpa 2 800)**

In this diagram, PRNU correction is performed using the cpa 2 algorithm with a peak target value of 600. Everything above 600 is clipped to 1x gain and everything below 150DN is clipped to 4x gain. To avoid clipping, ensure that the peak target value is equal to or greater than the maximum pixel value.

3.11 System Debugging

Setting the Video Mode and Displaying a Test Pattern

Use the test pattern to verify the proper timing and connections between the camera and the framegrabber.

To set the video mode, use the command:

Purpose: Generates a test pattern to aid in system debugging. The test patterns are useful for verifying proper timing and connections between the camera and the frame grabber. The following tables show each available test pattern.

Syntax: **svm *i***

Syntax Elements: ***i***

- | | |
|----------|--------------------------|
| 0 | Video mode |
| 1 | Test pattern 10 bit ramp |
| 2 | Test pattern 8 bit ramp |
| 3 | Test pattern fixed data |

Setting Thresholds

To set a lower threshold value that is checked for and reported in the end-of-line statistic, use the command:

Syntax: **slt *i***

Syntax Elements: ***i***

Lower threshold value. Available values are 0 to 1023.

Example: **slt 550**

To set an upper threshold value that is checked for and reported in the end-of-line statistic, use the command:

Syntax: **sut *i***

Syntax Elements: ***i***

Upper threshold value. Available values are 0 to 1023.

Example: **sut 1000**

3.12 Monitoring the Camera

Voltage Measurement

The command **vv** checks the camera's input voltage during power-up. If the voltage is within the proper range, the camera returns OK>. Otherwise, the camera returns an error message.

WARNING: The voltage measurement feature of the camera provides only approximate results (typically within 5%). It should not be used to set the applied voltage to the camera. The purpose of this test is to isolate gross problems with the supply voltages.

Temperature Measurement

The command **vt** measures and displays the temperature of the inside of the camera. It helps to determine whether the camera is operating within the recommended front plate temperature range of 25 to 40°C. **Note:** The internal camera temperature reading is usually 10 to 15°C higher than the front plate temperature.

Monitoring Tasks

The camera enters a warning state when any of camera's continuously running monitoring tasks detects a failure. Use the **wed i i** command, where the first parameter is the monitoring task and the second parameter is the enable or disable value, to display the status of all the defined monitoring tasks (if no parameter is passed) and/or to enable/disable specific monitoring tasks.

Note: If you are performing defect detection down to a single pixel, enabling monitoring tasks is not advisable because monitoring can occur during active video and could potentially provide erroneous data.

The following table lists the monitoring tasks:

Monitoring task number	MONITORING TASK	DESCRIPTION
0	All	Enable/disable all monitoring tasks
1	External voltage monitoring	Monitors all external camera voltages
2	Temperature monitoring	Monitors camera temperature
3	External SYNC presence	Monitors presence of external SYNC

Value	Function
0	Disable selected task
1	Enable selected task

Note: By default, all monitoring tasks are disabled.

Example: enable all monitoring tasks

wed 0 1

Example: disable EXSYNC presence

wed 3 0

3.13 Setting the Pre-trigger

A pre-trigger may be required for some frame grabbers.

To set the pre-trigger, use the command:

Syntax: **sp *i***

Syntax Elements: ***i***

Pretrigger value from 0 to 15.

Example: **sp 10**

3.14 Rebooting the Camera

The command **rc** reboots the camera. The camera starts up with the last saved settings.

4

Optical and Mechanical Considerations

4.1 Mechanical Interface

Figure 18: Mechanical Drawing

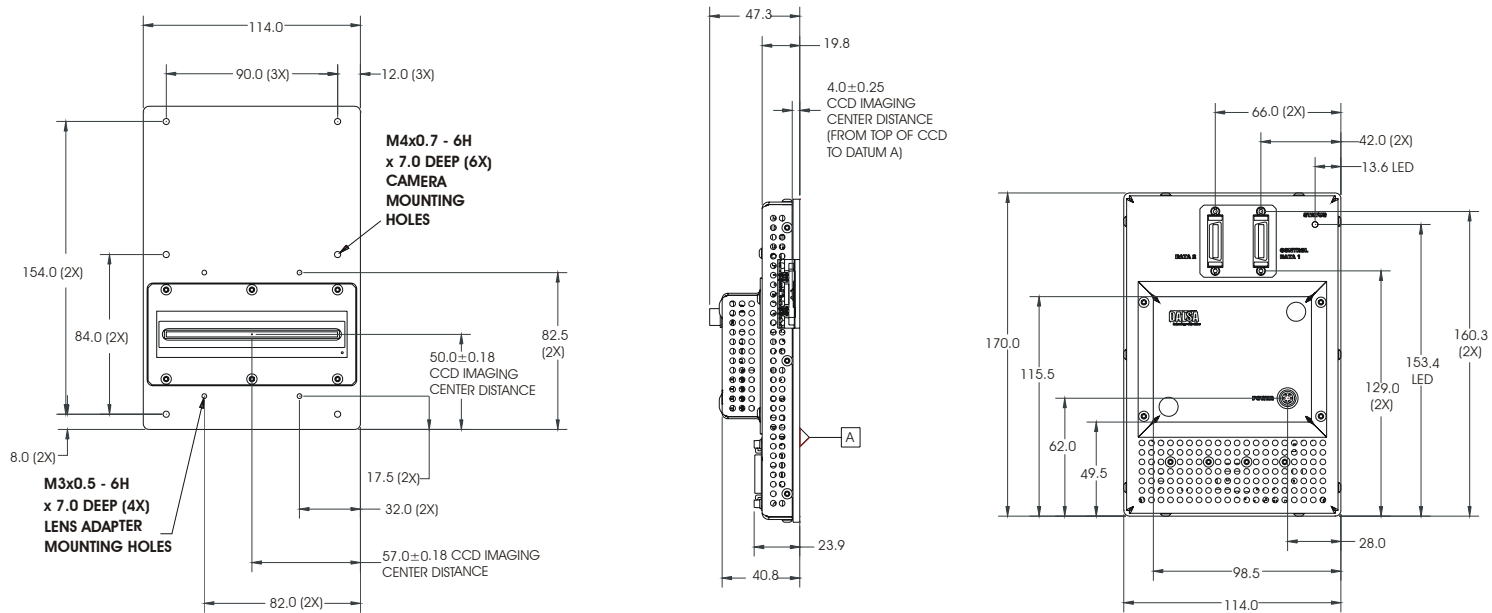
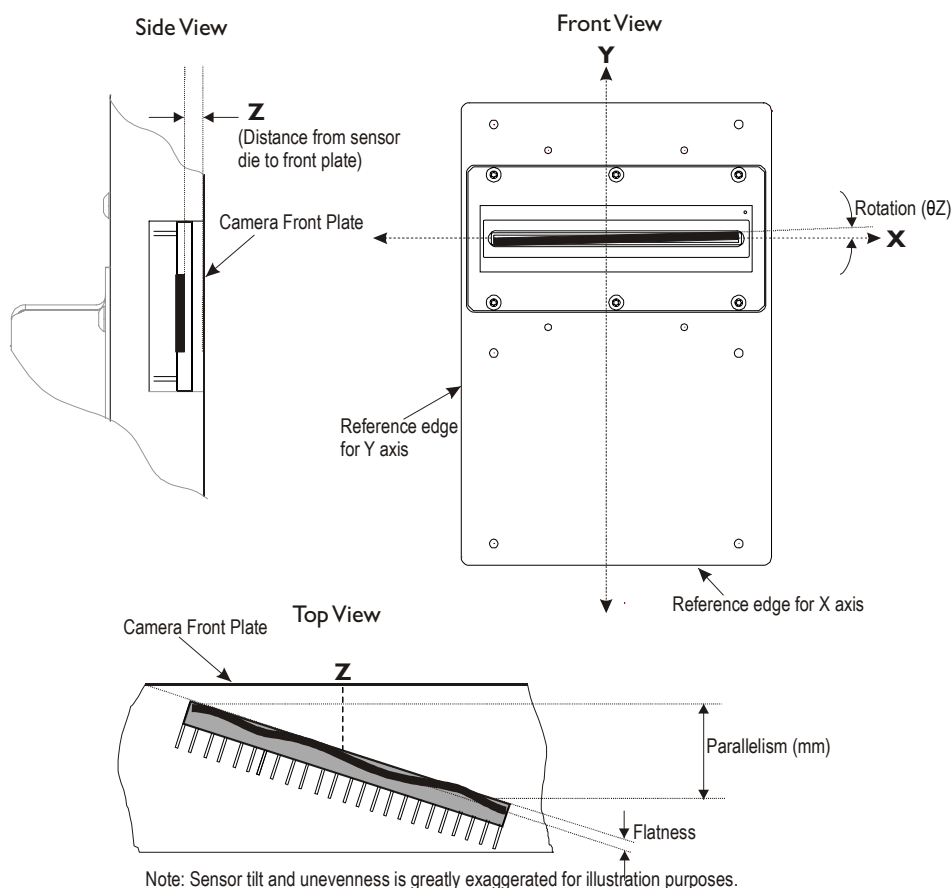


Figure 19: Sensor Alignment Reference

4.2 Optical Interface

Illumination

The amount and wavelengths of light required to capture useful images depend on the particular application. Factors include the nature, speed, and spectral characteristics of objects being imaged, exposure times, light source characteristics, environmental and acquisition system specifics, and more. DALSA's Web site, <http://vfm.dalsa.com/>, provides an introduction to this potentially complicated issue. See "Radiometry and Photo Responsivity" and "Sensitivities in Photometric Units" in the CCD Technology Primer found under the Application Support link.

It is often more important to consider exposure than illumination. The total amount of energy (which is related to the total number of photons reaching the sensor) is more important than the rate at which it arrives. For example, $5\mu\text{J}/\text{cm}^2$ can be achieved by exposing $5\text{mW}/\text{cm}^2$ for 1ms just the same as exposing an intensity of $5\text{W}/\text{cm}^2$ for $1\mu\text{s}$.

Light Sources

Keep these guidelines in mind when setting up your light source:

- LED light sources are relatively inexpensive, provide a uniform field, and longer life span compared to other light sources.
- Halogen light sources generally provide very little blue relative to IR.
- Fiber-optic light distribution systems generally transmit very little blue relative to IR.
- Some light sources age; over their life span they produce less light. This aging may not be uniform—a light source may produce progressively less light in some areas of the spectrum but not others.

Filters

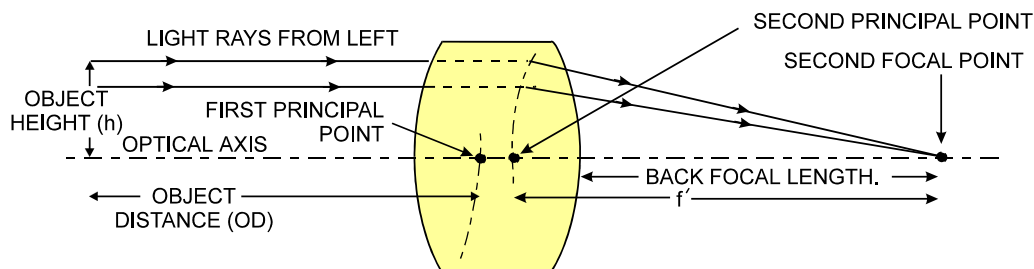
CCD cameras are extremely responsive to infrared (IR) wavelengths of light. To prevent infrared from distorting the images you scan, use a “hot mirror” or IR cutoff filter that transmits visible wavelengths but does not transmit wavelengths over 750nm. Examples are the Schneider Optics™ B+W 489, which includes a mounting ring, the CORION™ LS-750, which does not include a mounting ring, and the CORION™ HR-750 series hot mirror.

Lens Modeling

Any lens surrounded by air can be modeled for camera purposes using three primary points: the first and second principal points and the second focal point. The primary points for a lens should be available from the lens data sheet or from the lens manufacturer. Primed quantities denote characteristics of the image side of the lens. That is, h is the object height and h' is the image height.

The *focal point* is the point at which the image of an infinitely distant object is brought to focus. The *effective focal length* (f') is the distance from the second principal point to the second focal point. The *back focal length* (BFL) is the distance from the image side of the lens surface to the second focal point. The *object distance* (OD) is the distance from the first principal point to the object.

Figure 20: Primary Points in a Lens System



Magnification and Resolution

The magnification of a lens is the ratio of the image size to the object size:

$$m = \frac{h'}{h} \quad \text{where } m \text{ is the magnification, } h' \text{ is the image height (pixel size) and } h \text{ is the object height (desired object resolution size).}$$

By similar triangles, the magnification is alternatively given by:

$$m = \frac{f'}{OD}$$

These equations can be combined to give their most useful form:

$$\frac{h'}{h} = \frac{f'}{OD}$$

This is the governing equation for many object and image plane parameters.

Example: An acquisition system has a 512 x 512 element, 10 μ m pixel pitch area scan camera, a lens with an effective focal length of 45mm, and requires that 100 μ m in the object space correspond to each pixel in the image sensor. Using the preceding equation, the object distance must be 450mm (0.450m).

$$\frac{10\mu\text{m}}{100\mu\text{m}} = \frac{45\text{mm}}{OD} \quad OD = 450\text{mm (0.450m)}$$

5

Troubleshooting

The information in this chapter can help you solve problems that may occur during the setup of your camera. Remember that the camera is part of the entire acquisition system. You may have to troubleshoot any or all of the following:

power supplies	cabling
frame grabber hardware & software	host computer
light sources	optics
operating environment	encoder

Your steps in dealing with a technical problem should be:

1. Try the general and specific solutions listed in sections 5.1, 5.2 and 5.3.
2. If these solutions do not resolve your problem, see section 5.4 on getting product support.

5.1 Common Solutions

Connections

The first step in troubleshooting is to verify that your camera has all the correct connections.

Power Supply Voltages

Check for voltage presence at the camera power connector. Verify that all grounds are connected.

Data Clocking/Output Signals

To validate cable integrity, have the camera send out a test pattern and verify it is being properly received. Refer to section 3.11 System Debugging for further information on running test patterns.

5.2 Troubleshooting Using the Serial Interface

Communications

To quickly verify serial communications send the **h** (help) command. By sending the **h** and receiving the help menu, the serial communications are verified. If further problems persist, review Appendix B for more information on communications.

Verify Parameters

To verify the camera setup, send the **gcp** (get camera parameters) command.

Verify Factory Calibrated Settings

To restore the camera's factory settings send the **rfs** command.

After executing this command, send the **gcp** command to verify the factory settings.

Verify Timing and Digital Video Path

Use the test pattern feature to verify the proper timing and connections between the camera and the frame grabber and verify the proper output along the digital processing chain.

Verify Voltage

To check the camera's input voltages, use the **vv** command. If they are within the proper range, the camera returns OK>. Otherwise, the camera returns an error message. If an error occurs, verify the input voltage at the camera. If a problem persists, contact Technical Support. See section 5.4 Product Support for contact information.

5.3 Specific Solutions

No Output or Erratic Behavior

If your camera provides no output or behaves erratically, it may be picking up random noise from long cables acting as antennae. Do not attach wires to unused pins. Verify that the camera is not receiving spurious inputs (e.g. EXSYNC, if camera is using an internal signal for synchronization).

Line Dropout, Bright Lines, or Incorrect Line rate

Verify that the frequency of the internal sync is set correctly.

Noisy Output

Check your power supply voltage outputs for noise. Noise present on these lines can result in poor video quality. Low quality or non-twisted pair cable can also add noise to the video output.

Dark Patches

If dark patches appear in your output the optics path may have become contaminated. Clean your lenses and sensor windows with extreme care.

1. Take standard ESD precautions.
2. Wear latex gloves or finger cots
3. Blow off dust using a filtered blow bottle or dry, filtered compressed air.
4. Fold a piece of optical lens cleaning tissue (approx. 3" x 5") to make a square pad that is approximately one finger-width
5. Moisten the pad on one edge with 2-3 drops of clean solvent—either alcohol or acetone. Do not saturate the entire pad with solvent.
6. Wipe across the length of the window in one direction with the moistened end first, followed by the rest of the pad. The dry part of the pad should follow the moistened end. The goal is to prevent solvent from evaporating from the window surface, as this will end up leaving residue and streaking behind.
7. Repeat steps 2-4 using a clean tissue until the entire window has been cleaned.
8. Blow off any adhering fibers or particles using dry, filtered compressed air.

Horizontal Lines or Patterns in Image

A faulty or irregular encoder signal that is applied as the EXSYNC signal may result in horizontal lines due to exposure time fluctuations; ensure that your exposure time is regular. If you have verified that your exposure time is consistent and patterns of low frequency intensity variations still occur, ensure that you are using a DC or high frequency light source.

5.4 Product Support

If there is a problem with your camera, collect the following data about your application and situation and call your DALSA representative.

Note: You may also want to photocopy this page to fax to DALSA.

Customer name	
Organization name	
Customer phone number fax number	
Complete Product Model Number	
Complete Serial Number	
Your DALSA Agent or Dealer	
Acquisition System hardware (frame grabber, host computer, light sources, etc.)	
Acquisition System software (version, OS, etc.)	
Power supplies and current draw	
Data rate used	
Control signals used in your application, and their frequency or state (if applicable)	☐ EXSYNC ☐ BIN ☐ MCLK ☐ Other _____
Results when you run the gcp command	<i>please attach text received from the camera after initiating the command</i>
Detailed description of problem encountered.	<i>please attach description with as much detail as appropriate</i>

In addition to your local DALSA representative, you may need to call DALSA Technical Sales Support:

	North America	Europe	Asia
Voice:	519-886-6000	+49-8142-46770	519-886-6000
Fax:	519-886-8023	+49-8142-467746	519-886-8023

Appendix A

Camera Link™ Reference and Configuration Table

Camera Link is a communication interface for vision applications.

For years, the scientific and industrial digital video market has lacked a standard method of communication. Both framegrabber and camera manufacturers developed products with different connectors, making cable production difficult for manufacturers and very confusing for consumers. Increasingly diverse cameras and advanced signal and data transmissions have made a connectivity standard like Camera Link a necessity.

LVDS Technical Description

Low Voltage Differential Signaling (LVDS) is a high-speed, low-power general purpose interface standard. The standard, known as ANSI/TIA/EIA-644, was approved in March 1996. LVDS uses differential signaling, with a nominal signal swing of 350mV differential. The low signal swing decreases rise and fall times to achieve a theoretical maximum transmission rate of 1.923 Gbps into a loss-less medium. The low signal swing also means that the standard is not dependent on a particular supply voltage. LVDS uses current-mode drivers, which limit power consumption. The differential signals are immune to ± 1 V common volt noise. Camera Link uses an implementation of LVDS technology called Channel Link®.

Camera Signal Requirements

This section provides definitions for the signals used in the Camera Link interface. The standard Camera Link cable provides camera control signals, serial communication, and video data.

Video Data

The Channel Link technology is integral to the transmission of video data. Image data and image enable signals are transmitted on the Channel Link bus. Four enable signals are defined as:

- FVAL—Frame Valid (FVAL) is defined LOW for valid lines.
- LVAL—Line Valid (LVAL) is defined HIGH for valid pixels.
- DVAL—Data Valid (DVAL) is defined HIGH when data is valid.
- Spare— A spare has been defined for future use.

All four enable signals must be provided by the camera on each Channel Link chip. All unused data bits must be tied to a known value by the camera. For more information on image data bit allocations, refer to the official Camera Link specification on the vfm.dalsa.com Web site.

Camera Control Signals

Four LVDS pairs are reserved for general-purpose camera control. They are defined as camera inputs and framegrabber outputs. Camera manufacturers can define these signals to meet their needs for a particular product. DALSA has defines these signals

Table 10: Standard DALSA Naming Conventions

Camera Link Name	Camera Configuration
CC1	EXSYNC
CC2	PRIN
CC3	Not Used
CC4	Not Used

Communication

Two LVDS pairs have been allocated for asynchronous serial communication to and from the camera and framegrabber. Cameras and framegrabbers must support 9600 baud, as a minimum requirement. These signals are

- SerTFG – Differential pair with serial communications to the framegrabber.
- SerTC – Differential pair with serial communications to the camera.

The serial interface will have the following characteristics: one start bit, one stop bit, no parity, and no handshaking. It is recommended that framegrabber manufacturers supply both a user interface and a software application programming interface (API) for using the asynchronous serial communication port. The user interface will consist of a terminal program with minimal capabilities of sending and receiving a character string and sending a file of bytes. The software API will provide functions to enumerate boards and send or receive a character string. See Appendix B in the Official Camera Link specification on the vfm.dalsa.com Web site.

Power

Power will not be provided on the Camera Link connector. The camera will receive power through a separate cable. DALSA defines our own power connector, current, and voltage requirements.

A1 Camera Link™ Configuration Table

The following table provides tap reconstruction information. DALSA is working with the machine vision industry to use this table as the basis for auto configuration. Visit the <http://vfm.dalsa.com> Web site and view the DALSA Camera Link Implementation Road Map document, 03-32-00450, for further details.

Interface Parameters

Table 11: Framegrabber Interface Parameters

Item (when programmable configuration the options are separated with a)	
Imager Dimension <1,2 or 1 2>	1
Imager Columns<number of active columns, X>	12288
Imager Rows<number of active rows, Y> Line Scan/TDI are defined as 1	1
Number of Imager Taps <1,2,3.....>	8
Tap Clock Rate <xx MHz>	40
Camera Standard <NTSC, PAL, VS, VW, MW>	VS
Number of Camera Configurations<1,2,3,...>	1
Configuration Definition Cx= HDW, Number of Output Taps, Bit Width, Number of Processing Nodes where Cx is the configuration ID x is <1,2,3...> HDW is <Base, Medium, Full> Number of Output Taps is <1,2,3...> Bit width is <8, 10,12...> Number Processing Nodes is <1 or 2>	C1 = Full, 8, 8,1
Tap Reconstruction In some configurations the reconstruction may change. C0 is the default output format and must be listed. Output configurations that don't conform are listed separately. <Cx,Tn (Column Start, Column End, Column Increment, Row Start, Row End, Row Increment)>	C0, T1 (1, 3071, 2, 1, 1, 1) C0, T2 (2, 3072, 2, 1, 1, 1) C0, T3 (3073, 6143, 2, 1, 1, 1) C0, T4 (3074, 6144, 2, 1, 1, 1) C0, T5 (9215, 6145, -2, 1, 1, 1) C0, T6 (9216, 6146, -2, 1, 1, 1) C0, T7 (12287, 9217, -2, 1, 1, 1) C0, T8 (12288, 9218, -2, 1, 1, 1)
Camera Color <Hybrid, Mono, Pattern, Solid>	Mono
RGB Pattern Size <(T1,Columns*Rows)(T2,Columns*Rows)(T3,Columns*Rows....>	(T1, 1*1) (T2, 1*1) (T3, 1*1) (T4, 1*1) (T5, 1*1) (T6, 1*1) (T7, 1*1) (T8, 1*1)
Color Definition (Column, Row, Color) Where color is R,G,B	T1=(1,1,M) T2=(1,1,M) T3=(1,1,M) T4=(1,1,M) T5=(1,1,M) T6=(1,1,M) T7=(1,1,M) T8=(1,1,M)
Row Color Offset <0,1,2,3...>	0
Column Color Offset <0,1,2,3...>	0
Row Binning Factor <1,2,3 or 1 2 3>	1
Column Binning Factor <1,2,3 or 1 2 3>	1

Item (when programmable configuration the options are separated with a)	
Pretrigger Pixels <0,1,2...or 0..15>	0
Pretrigger Lines <0,1,2.. or 0..15>	0
Line Time Minimum <xx ms>	.003
Line Time Maximum <xx μ s>	1000
Internal Line/Frame Time Resolution <xx ns> 0 if not applicable	TBD
Pixel Reset Pulse Minimum Width <xx ns> 0 if not applicable	TBD
Internal Pixel Reset Time Resolution <xx ns> 0 if not applicable	TBD
Pixel Reset to Exsync Hold time <xx ns>	TBD
BAUD Rate <9600....>	9600, 19200, 57600, 115200
CC1 <Exsync>	EXSYNC
CC2 <Spare>	PRIN
CC3 <Forward, Spare>	Spare
CC4 <Spare>	Spare
DVAL out <Strobe Valid, Alternate>	High
LVAL out <Frame Valid, Alternate>	High
Spare out <Spare>	Not Used
FVAL out	Low

Appendix B

Error Handling and Command List

B1 Error Handling

The following tables list the codes for major errors, informal messages, and monitoring task messages.

Table 12: Error Codes

Major Error Codes		
Code	Description	Suggested Cause
0	SUCCESS	Command executed without major error detected
1	Internal camera error (PIXEL INDEX)	Internal software error trap
2	Internal camera error (RESULT CODE)	Internal software error trap
3	Invalid command	Command not recognized
4	Command parameters incorrect or out of range	Command parameters are invalid or out of range
5	Command not available in current exposure mode	ssf and set are allowed only in mode 2 (ssf and set) and in mode 6 (set)
10	Camera memory check failure	Memory test of external RAM failed
11	Unable to configure DSP	DSP (FPGA) configuration failure
12	DSP configuration reset failure	DSP (FPGA) could not be placed in configuration mode
13	Process timed out, check for the presence of external signals	gl,gla,cao,cag,ccf,ccp timed out. Current exposure mode requires external SYNC, however SYNC signal not present
14	DSP echo test error	DISC bus communication test failure
18	External supply voltage is out of specification	vv command result
19	The camera's temperature is outside the specified operating range	vt command result

Major Error Codes		
Code	Description	Suggested Cause
20	Video level out of range, calibration canceled	Level of video signal is out of range for calibration procedure attempted (ccf, ccp)
21	Analog offset calibration failure	Analog offset calibration failure (could not tune the analog offset to obtain targeted video level)
22	Analog gain calibration failure	Analog gain calibration failure (could not tune the analog gain to obtain targeted video level)
23	CRC check failure while attempting to restore the camera settings	Camera setting will initialize to default settings, since restore of USER/FACTORY settings failed (internal micro EE memory failure)
24	Camera settings not saved	rus, rfs attempted but settings were not saved
25	Pixel coefficients write failure	Failure while writing pixel coefficients to EEROM
26	I2C communication fault while accessing temperature sensor	Serial communication fault
27	Timeout waiting for DISC SYNC to go LOW	Internal communication protocol error

Informal Message Codes		
Code	Description	Suggested Cause
1	INFO: CRC check failure while attempting to restore calibration status	Pixel calibration status will be set to NOT CALIBRATED (internal micro EEROM failure)
2	INFO: CRC check failure while attempting to restore pixel coefficients	All pixel coefficients will be reset to zero (external EEROM failure)
4	INFO: Flash memory ID error	Reported from boot process, only if DSP configuration fails (possible cause: communication error with serial flash memory)
8	INFO: DSP configuration file missing or corrupt	Reported from boot process, only if DSP configuration fails (possible cause)
16	INFO: Serial communication failure while accessing external ADC chip	Reported from boot process if communication verification fails with external ADC chip (camera voltage measurement, SPI)
32	INFO: Calibration may be out-of-specification (PRNU coefficient clipped)	ccp : at least one PRNU coefficient > 511
64	INFO: Calibration may be out-of-specification (FPN coefficient clipped)	ccf : at least one FPN coefficient > 127

Informal Message Codes		
Code	Description	Suggested Cause
128	INFO: Calibration may be out-of-specification (DO+FPN > 511)	ccf : at least one pixel -> FPN coefficient > 511
256	INFO: Changing analog settings of calibration mode voids pixel calibration	sao, sg in calibration mode after calibration has been done
512	INFO: For better calibration results, run FPN calibration first	ccp, cpa : ccp or cpa called before ccf

Monitoring Task Message Codes		
Code	Description	Suggested Cause
1	WARNING: One or more voltages out of specification	At least one of voltages is out of specification
2	WARNING: Camera temperature exceeds specified limit	Current camera temperature exceeds specification limit
4	WARNING: External SYNC not detected	External SYNC not detected
16	WARNING: Analog gain is over/under the specification	Current analog gain setting is out of specification

B2 All Available Commands

As a quick reference, the following table lists all of the commands available to the camera user. For detailed information on using these commands, refer to Chapter 3.

Parameters:

t = tap id

i = integer value

f = real number

s = string

[] = optional parameter

Command Mnemonic	Command	Parameters	Description
calibrate analog gain	cag	t i	Calibrates the analog gain to a specified peak target value. The first parameter is the tap selection 1 to 8 , 0 for all taps. The second parameter is the target value in a range from 256 to 1004 DN. Refer to Calibrating Analog Offset and Analog Gain Values on page 32 for details.
calibrate analog offset	cao	t i	Calibrates the analog offset to a specified peak target value. The first parameter is the tap selection 1 to 8 , 0 for all taps. The second parameter is the target value in a range from 1 to 400 DN. Refer to Calibrating Analog Offset and Analog Gain Values on page 32 for details.

Parameters:

t = tap id**i** = integer value**f** = real number**s** = string**[]** = optional
parameter

Command Mnemonic	Command	Parameters	Description
correction calibrate fpn	ccf	[i]	Start FPN coefficient calibration. Dark calibration automatically calibrates FPN coefficients and digital offset. Optional parameter is the offset value in a range from 1 to 400DN . Refer to FPN (Dark) Calibration on page 39 for details.
correction calibrate prnu	ccp	[i]	Start PRNU coefficient calibration. Optional parameter is an analog gain value in a range from 256 to 1004DN . Refer to PRNU (White Light) Calibration on page 39 for details.
calculate camera gain	ccg	i t i	Calculates the camera gain according to the selected algorithm. i = Calibration algorithm to use. 1 = This algorithm adjusts analog gain so that 8% to 13% of tap ROI pixels are above the specified target value. 2 = This algorithm adjusts analog gain so that the average pixel value in tap's ROI is 97 to 99% of the specified target value. t = Tap value. Use 0 for all taps or 1 to 8 for individual tap selection. i = Calibration target value in a range from 1024 to 4055DN (12 bit LSB).

Parameters:

t = tap id**i** = integer value**f** = real number**s** = string**[]** = optional
parameter

Command Mnemonic	Command	Parameters	Description
calculate PRNU algorithm	cpa	i i	Performs PRNU calibration according to the selected algorithm. The first parameter is the algorithm where i is: 1 = This algorithm first adjusts each tap's analog gain so that 8-13% of pixels within a tap are above the value specified in the target value parameter. PRNU calibration then occurs using the peak pixel in the region of interest. (Identical to ccp i) 2 = Calculates the PRNU coefficients using the entered target value as shown below: $\text{PRNU Coefficient} = \frac{\text{Target}}{(\text{AVG Pixel Value}) - (\text{FPN} + \text{sdo value})}$ The calculation is performed for all sensor pixels but warnings are only applied to pixels in the region of interest. This algorithm is useful for achieving uniform output across multiple cameras. 3 = This algorithm includes an analog gain adjustment prior to PRNU calibration. Analog gain is first adjusted so that the average pixel value in tap's ROI is within 97 to 99% of the specified target value. It then calculates the PRNU coefficients using the target value as shown below: $\text{PRNU Coefficient}_i = \frac{\text{Target}}{(\text{AVG Pixel Value}) - (\text{FPN} + \text{sdo value})}$ The calculation is performed for all sensor pixels but warnings are only applied to pixels in the region of interest. This algorithm is useful for achieving uniform output across multiple cameras. Recommended peak video output before PRNU calibration is 5-20% lower than target. The second parameter is the target value to use in a range from 256 to 1004DN.

Parameters:

t = tap id**i** = integer value**f** = real number**s** = string**[]** = optional
parameter

Command Mnemonic	Command	Parameters	Description
correction set sample	css	i	Set number of line samples averaged for pixel coefficient calculations or for output of gla command. Values: 256 , 512 , and 1024 . Refer to section Returning Multiple Lines of Video on page 29 for details.
display pixel coefficients	dpc	[i i]	Displays the 16-bit FPN and PRNU value for each pixel. Optional pixel start and end values in a range from 1 to 12288 . Refer to Returning Calibration Results and Errors on page 40 for details.
enable pixel coefficients	epc	i i [i]	Sets whether pixel coefficients are enabled or disabled. The first parameter sets the FPN coefficients where i is: 0 = FPN coefficients disabled 1 = FPN coefficients enabled The second parameter sets the PRNU coefficients where i is: 0 = PRNU coefficients disabled 1 = PRNU coefficients enabled The last optional parameter turns current digital offset setting on or off. 0 = Digital offset turned off and set to zero 1 = Digital offset enabled and returned to previous setting Refer to section Saving, Loading, Resetting, Enabling, and Disabling Pixel Coefficients on page 42 for details.
get camera model	gcm		Read the camera model number.
get camera parameters	gcp		Read all of the camera parameters. Refer to section 3.1 Retrieving Camera Settings for details.
get camera serial	gcs		Read the camera serial number.
get camera version	gcv		Read the firmware version and FPGA version.
get fpn coeff	gfc	i	Read the FPN coefficient where i is the pixel in a range from 1 - 12288 . Refer to section Setting and Reading a Pixel's PRNU and FPN Coefficient for details.

Parameters:

t = tap id**i** = integer value**f** = real number**s** = string**[]** = optional
parameter

Command Mnemonic	Command	Parameters	Description
get line	gl	[i i]	Get a line of raw video (no digital processing or test pattern) displaying one pixel value after another and the minimum, maximum, and mean value of the sampled line. Optional pixel start and end values in a range from 1 to 12288 . Refer to section 3.9 Returning Video Information for details.
get line average	gla	[i i]	Read the average of line samples. Optional pixel start and end values in a range from 1 to 12288 . Refer to section 3.9 Returning Video Information for details.
get prnu coeff	gpc	i	Read the PRNU coefficient 1 to 12288 . Refer to section Setting and Reading a Pixel's PRNU and FPN Coefficient for details.
get sensor serial	gss		Read the sensor serial number.
help	h		Display the online help. Refer to Online Help on page 17 for details.
load pixel coefficients	lpc		Loads the previously saved pixel coefficients from non-volatile memory. The optional parameter specifies which sets of coefficients to load: 1 = Coefficient set one 2 = Coefficient set two If no parameter is specified, coefficient set one is loaded. Refer to section Saving, Loading, Resetting, Enabling, and Disabling Pixel Coefficients for details.
region of interest	roi	x1 x2	Sets the pixel range affected by the cag , cao , gl , gla , and ccp commands. The parameters are the pixel start (x1) and end (x2) values in a range from 1 to 12288 . Refer to section 3.8 Setting a Region of Interest for details.
reset camera	rc		Reset the entire camera (reboot).

Parameters:

t = tap id**i** = integer value**f** = real number**s** = string**[]** = optional
parameter

Command Mnemonic	Command	Parameters	Description
reset pixel coefficients	rpc		Reset the pixel coefficients and digital offset to 0. The digital offset will also be temporarily reset to zero but the stored digital offset settings will not be overwritten. Rebooting the camera or sending the rus command will restore the saved digital offset values. Pixel coefficients will remain at zero until new values are saved with the wpc command or previously saved coefficients are reloaded using the lpc command. Refer to section Saving, Loading, Resetting, Enabling, and Disabling Pixel Coefficients for details.
restore factory settings	rfs		Restore the camera's factory settings. FPN and PRNU coefficients reset to 0. Refer to section 3.5 Saving and Restoring Settings for details.
restore user settings	rus		Restore the camera's last saved user settings and FPN and PRNU coefficients. Refer to section 3.5 Saving and Restoring Settings for details.
set analog offset	sao	t i	Sets the analog offset. t = Tap value. 0 for all taps or 1-8 for individual tap selection. i = Controls the digital analog converter (DAC) in a range from 0 to 1023 , that sets analog offset. Offset increases with higher values. Refer to section Setting Analog Offset on page 31 for details.
set baud rate	sbr	i	Set the speed of camera serial communication port. Baud rates: 9600 , 19200 , 57600 , and 115200 . Default: 9600. Refer to section 3.6 Setting Baud Rate for details.

Parameters:

t = tap id**i** = integer value**f** = real number**s** = string**[]** = optional
parameter

Command Mnemonic	Command	Parameters	Description
set digital offset	sdo	t i	Subtracts the input value from the video signal. Digital offset is reset to zero after issuing the ccf command. Use the digital offset command to reset the offset to zero if you perform PRNU calibration (ccp) without FPN calibration (ccf). t = Tap value. 0 for all taps or 1-8 for individual tap selection. i = The offset in a range from 0 to 511DN. Refer to Setting Digital Offset on page 42 for details.
set exposure mode	sem	i	Sets the exposure mode to use where i is: 2 = Internal SYNC and PRIN, programmable line rate and exposure time using commands ssf and set. 3 = External SYNC, internal PRIN, maximum exposure time (no shuttering). 4 = Smart EXSYNC 5 = External SYNC and PRIN 6 = External SYNC, internal PRIN, programmable exposure time. 7 = Internal programmable SYNC, maximum exposure time. Refer to section 3.7 Setting Exposure Mode and Line Rate for details.
set exposure time	set	f	Set the exposure time in exposure mode 2 or 6 (see sem command). Value is a floating point number in a range from 3.00μsec to 1000.00μsec. Refer to section 3.7 Setting Exposure Mode and Line Rate for details.
Set FPN coefficient	sfc	i i	Sets an individual pixel's coefficient value. i = The pixel to set in range from 1 to 12288. i = The coefficient value to set in a range from 0 to 511. Refer to FPN Coefficients on page 44 for details.

Parameters:

t = tap id**i** = integer value**f** = real number**s** = string**[]** = optional
parameter

Command Mnemonic	Command	Parameters	Description
set gain	sg	t f	Sets the analog gain. t = Tap value. 0 for all taps or 1-8 for individual tap selection. f = Analog gain setting in a range from -10 to 10 dB. Refer to Setting Analog Gain on page 32 for details.
set lower threshold	slt	i	Sets the lower threshold value that is checked for and reported in the end-of-line statistic. i = Lower threshold value with a range from 0 to 1023 DN. Refer to Setting Thresholds on page 50 for details.
set pretrigger	sp	i	Sets the pretrigger to a value from 0 or 15 . Refer to section 3.13 Setting the Pre-trigger for details.
set prnu coeff	spc	i i	Set the PRNU coefficient. The first parameter is the pixel number within the range 1 to 12288 . The second parameter is a specified value within the range 1 to 3071 DN where $PRNU = 1 + \frac{i}{1024}$ Refer to Setting and Reading a Pixel's PRNU and FPN Coefficient on page 44 for details.
set subtract background	ssb	t i	Subtracts the input value from the output signal. t = Tap value. 0 for all taps or 1-8 for individual tap selection. i = Subtracted value in a range from 0 to 768 DN. Refer to Subtracting Background on page 41 for details.
set sync frequency	ssf	f	Sets the line rate, in exposure mode 7, to a value from 5000 to 24000 Hz. Refer to section 3.7 Setting Exposure Mode and Line Rate for details.
set system gain	ssg	t i	Sets the digital gain. t = Tap value. 0 for all taps or 1-8 for individual tap selection. i = Gain value in a range from 4096 to 16384 . Refer to Setting Digital Gain on page 41 for details.

Parameters:

t = tap id**i** = integer value**f** = real number**s** = string**[]** = optional
parameter

Command Mnemonic	Command	Parameters	Description
set upper threshold	sut	i	Sets the upper threshold value that is checked for and reported in the end-of-line statistic. i = 0 to 1023 DN Refer to Setting Thresholds on page 50 for details
set video mode	svm	i	Sets the video mode, where i is: 0 = Video mode 1 = Test pattern 10 bit ramp. 2 = Test pattern 8 bit ramp. 3 = Test pattern fixed data. Refer to section 3.11 System Debugging for details.
verify temperature	vt		Check the internal temperature of the camera. Refer to section 3.12 Monitoring the Camera for details.
verify voltage	vv		Check the camera voltages and return OK or fail. Refer to section 3.12 Monitoring the Camera for details.
warning enable disable	wed	[i] [i]	Read enable/disable status of all defined monitoring tasks. Optionally, the first parameter selects a monitoring task and the second parameter enables/disable the selected task. Refer to section 3.12 Monitoring the Camera for details.
write pixel coeffs	wpc	[i]	Writes all current pixel coefficients and epc settings to EEPROM. The optional parameter allows you to save more than one set of parameters where: 1 = Coefficient set one 2 = Coefficient set two If no parameter is specified, coefficients are saved as set one. Refer to section 3.5 Saving and Restoring Settings for details.
write user settings	wus		Writes all of the user settings to the EEPROM. Refer to section 3.5 Saving and Restoring Settings for details.

Appendix C

Revision History

Revision Number	Change Description
00	Preliminary release
01	Added Sensor Alignment drawing in Chapter 4, page 48 Added Parallelism and θ_z spec to Camera Specifications table in Chapter 1.
02	Added the command cpa (calculate PRNU algorithm) to section 3.10.5 Calibration Commands and to section B2 All Available Commands. Added the optional parameter to the wpc and lpc commands in sections 3.5 Saving and Restoring Settings, B2 All Available Commands, and to 3.10.4 Digital Signal Processing. These commands can now save and load two sets of pixel coefficients. Added Figure 17: PRNU Calibration using a Peak Target Value (ROI=1-12288) (cpa 2 800). Reworked section 3.10 Analog and Digital Signal Processing Chain.
03	Added algorithm 3 to the cpa command in section 3.10.5 Calibration Commands and to section B2 All Available Commands. Added the ccg command to section 3.10.2 Analog Signal Processing: Setting Analog Gain and Offset and to section B2 All Available Commands.

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